# MineSet™
# User's Guide

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St. Peter's Basilica image courtesy of ENEL SpA and InfoByte SpA. Disk Thrower image courtesy of Xavier Berenguer, Animatica.

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# About This Guide

The *MineSet User's Guide* describes the features and capabilities of this suite of four database mining and nine visualization tools. Current information about the MineSet product can be found on the World Wide Web at
http://www.sgi.com/Products/software/MineSet

## Audience for This Guide

If you are using the Tool Manager to extract data from a database into the MineSet tools, you should understand database structures. It also would be helpful to know SQL.

If you are configuring the tools directly (through the configuration files, or through the command line in the case of the association rules), you should have some knowledge of UNIX as well as some programming experience.

Once the data has been loaded into the various visualization tools, you will not need a database or programming background, although you will be able to interpret the displays more easily if you have an understanding of the data and what it represents.

## Structure of This Document

In addition to this preface, the documentation for MineSet consists of the following chapters:

Chapter 1, “Getting Started”
This provides a brief overview of each MineSet tool and describes the processes that occur when invoking and using a tool.

Chapter 2, “Setting Up MineSet”
This chapter describes how to set up MineSet by configuring the DataMover.

Chapter 3, “The Tool Manager”
This chapter describes the menus and functions of the initial interface for invoking tools and tells how to produce their respective configuration files.

Chapter 4, “Using the Statistics Visualizer”
This chapter provides a description of the Statistics Visualizer. This tool is valuable for comprehending variations in statistics by comparing box plots and histograms.

Chapter 5, “Using the Tree Visualizer”
This chapter provides a complete description of the Tree Visualizer tool interface. This tool is valuable for visualizing hierarchical data.

Chapter 6, “Using the Map Visualizer”
This chapter provides a complete description of the Map Visualizer interface. This tool is valuable for visualizing data that is connected with a geographical location.

Chapter 7, “Using the Scatter Visualizer”
This chapter provides a complete description of the Scatter Visualizer interface. This tool is valuable for visualizing multidimensional data.

Chapter 8, “Using the Splat Visualizer”
This chapter provides a complete description of the Splat Visualizer. This tool, which is particularly well suited for application to very large datasets, lets you visually analyze relationships among several variables, either statically or by animation.

Chapter 9, “Using the Rules Visualizer”
This chapter provides a complete description of the Rules Visualizer. This tool is valuable for mining large datasets and visualizing correlations in that data.

Chapter 10, “MineSet Inducers and Classifiers”
This chapter provides a brief introduction to classifiers and regressors, and the algorithms that generate them, called inducers. Specifically, it introduces the three MineSet classifiers: Decision Tree, Option Tree and Evidence.

Chapter 11, “Inducing and Visualizing the Decision Tree Classifier”
This chapter describes how to generate and use the Decision Tree Classifier. This tool is valuable for classifying data according to a set of attributes by making a series of decisions based on those attributes.

Chapter 12, “Inducing and Visualizing the Option Tree Classifier”
This chapter describes how to generate and use the Option Tree Classifier. This tool assigns each record to a class. Option trees can contain special option nodes that allow the classifier to consider the influence of splitting on multiple attributes simultaneously.

Chapter 13, “Inducing and Visualizing the Evidence Classifier”
This chapter describes how to generate and use the Evidence Classifier. This tool is valuable for classifying data by examining the probabilities of a specified result occurring based on a given attribute.

Chapter 14, “Inducing and Visualizing the Decision Table”
This chapter describes how to generate and use the Decision Table Classifier. This tool is useful for examining data and visualizing correlations between pairs of attributes.

Chapter 15, “Inducing and Visualizing the Regression Tree”
This chapter describes how to generate and use the Regression Tree Classifier. This tool is useful for predicting attributes based on continuous values, such as occur in real life.

Chapter 16, “Inducing and Visualizing Clustering”
This chapter describes how to generate and use clustering to explore data. This tool is useful to detect groups of records that have similar characteristics.

Chapter 17, “Column Importance”
This chapter provides a complete description of the column importance tool. It also describes the relationship between column importance and the importance ranking in the other data mining tools.

Chapter 18, “Selection and Drill-Through”
This chapter describes the how to use multiple selection in the MineSet tools, as well as the concept of drill-through.

Chapter 19, "File Exchange Between MineSet and SAS"
This chapter describes the support for file exchanges between the MineSet and SAS formats.

Chapter 20, "MineSet Web Extensions"
This chapter describes the MineSet extensions that are provided to let you create or view visualizations and/or interact with MineSet over the web.

Appendix A, "Flat File Support for MineSet"
This appendix describes the *.schema* and the *.data* files that are required for MineSet to read flat files.

Appendix B, "Creating Data and Configuration Files for the Tree Visualizer"
This appendix explains the required formats of the Tree Visualizer data and configuration files.

Appendix C, "Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer"
This appendix explains the required formats of the Map Visualizer data, configuration, hierarchy, and *.gfx* files.

Appendix D, "Creating Data and Configuration Files for the Scatter Visualizer"
This appendix explains the required formats of the Scatter Visualizer data and configuration files.

Appendix E, "Creating Data and Configuration Files for the Splat Visualizer"
This appendix describes the format of the Splat Visualizer's data file.

Appendix F, "Creating Data and Configuration Files for the Rules Visualizer"
This appendix explains the required formats of the Rules Visualizer data and configuration files.

Appendix G, "Format of the Evidence Visualizer's Data File"
This appendix describes the format of the Evidence Visualizer's data file.

Appendix H, "Creating Data and Configuration Files for the Decision Table Visualizer"
This appendix describes the format of the Decision Table's data file.

Appendix I, “Command-Line Interface to MIndUtil: Analytical Data Mining Algorithms”
This appendix describes how the server side of the MineSet images handles classifiers, regressors, discretization, column importance, file conversions, and their options.

Appendix J, “Nulls in MineSet”
This appendix describes how MineSet supports nulls in the data access tools, the mining tools, and the visualization tools.

Appendix K, “Further Reading and Acknowledgments”
This appendix lists reference sources for further reading about concepts and their implementations used in the MineSet tools. It also lists acknowledgments for data sources used in the examples provided with these tools.

## Illustration in This Guide

The hard copy of this documentation provides all screen shots and illustrations in black and white. The online version, however, provides these visuals in full, original color. Thus, if you are reading the hard copy version and find a particular graphic or screen shot difficult to see, go to the respective page of the online version for greater clarity.

## Typographical Conventions

The following type conventions and symbols are used in this guide:

*Italics* Executable names, filenames, program variables, tools, utilities, variable command-line arguments, and variables to be supplied by the user in examples, code, and syntax statements.

**Bold** Keywords

`Fixed-width type`
On-screen command-line text and prompts.

**`Bold fixed-width type`**
User input, including keyboard keys (printing and non-printing); literals supplied by the user in examples, code, and syntax statements.

[ ] Syntax statement arguments surrounded by square brackets denote that these arguments are optional.

*Chapter 1*

# Getting Started

This introduction provides an overview of MineSet™, an integrated suite of data mining and visualization tools, and describes the basic tool execution scenario.

**Note:** Before using any of the MineSet tools, follow the installation and licensing instructions in the MineSet release notes. Then your system administrator must set up the DataMover configuration file. You also can choose to set up various options. The setup details are described in Chapter 2.

## MineSet Tools Suite

The MineSet suite of tools lets you mine and graphically display quantitative information in ways that can help you better visualize, explore, and understand your data. This suite of data mining and analysis tools can help you organize and examine your data in new and meaningful ways. The mining tools automatically find patterns and build models that can be viewed using the visualization tools. The visualization tools can also be applied directly to the data for further insights. These tools provide an enabling power that lets you gain a deeper, intuitive understanding of your data, and helps you discover hidden patterns and important trends.

These tools provide a highly interactive, three-dimensional (3D) visual interface that lets you manipulate visual objects on the screen, as well as search, filter and perform animations. This ability to visualize and survey complex data patterns can prove invaluable for decision support, in business intelligence and knowledge management.

The MineSet suite consists of three basic components:

- **a centralized control module**, consisting of a graphical user interface tool called the *Tool Manager*, and a process called the *DataMover*, which runs on the server part of MineSet's client/server architecture.
- **analytical data mining**, with nine data mining tools:
  - Association Rules Generator
  - Automatic Binning
  - Cluster Generator
  - Column Importance
  - Decision Table Inducer and Classifier
  - Decision Tree Inducer and Classifier
  - Evidence Inducer and Classifier
  - Option Tree Inducer and Classifier
  - Regression Tree Inducer and Regressor
- **visualization tools**, which let you view your data using ten different visual metaphors:
  - Cluster Visualizer
  - Decision Table Visualizer
  - Evidence Visualizer
  - Map Visualizer
  - Record Viewer
  - Rules Visualizer
  - Scatter Visualizer
  - Splat Visualizer
  - Statistics Visualizer
  - Tree Visualizer

The following sections provide a brief description of each of the above-mentioned components.

## Tool Manager

Each of the mining and visualization tools described below can be configured and started via a consistent graphical user interface known as the Tool Manager. The Tool Manager

- connects you to the server on which the analytical mining and transformations are performed
- lets you access, query and transform data
- creates configuration files for each tool

## DataMover

The DataMover is a process that runs on the server on behalf of the user. The DataMover

- connects to databases, flat files (ASCII or binary), and retrieves the data
- invokes the mining tools
- performs additional data manipulation such as binning and aggregation
- returns the data to the Tool Manager for distribution to the visualization tools
- can store the data in files on the server or client for future operations.

## Association Rules Generator

The Association Rules Generator processes an input file, then generates an output file consisting of rules. These rules indicate the frequency with which one item occurs in a record along with another item. The strength of the association is quantified by three numbers.

- The first number, the *predictability* of the rule, quantifies how often an item *X* and an item *Y* occur together as a fraction of the number of records in which *X* occurs. For example, given that someone has bought milk, how often do they also buy eggs.
- The second number, the *prevalence* of the rule, quantifies how often *X* and *Y* occur together in the file as a fraction of the total number of records. For example, how often were milk and eggs bought together.
- The third number is *expected predictability*. This gives an indication of what the predictability would be if there were no relationship between the items in the record. For example, how often were eggs bought, regardless of whether milk was bought as well.

### Automatic Binning

Automatic Binning groups together closely spaced numerical data into discrete categories. Some data mining algorithms, such as the Decision Tree Inducer, require some discrete (categorical) data; similarly, visualization tools such as the Splat Visualizer may need data categorized in this way.

MineSet can automatically determine these categories, or you can determine how you need it done. Requirements can be as simple as dividing the data into three equal ranges; or as complex as having MineSet choose ranges differentiated according to some chosen attribute, at the same time discarding the outer five percent of the data as outliers.

### Clustering

Clustering segments data into similar groups or clusters. For example, you can ask MineSet to suggest a segmentation of customers into five distinct groups, without giving any further parameters. Once the clustering operation has been run, you can view the results in the Cluster Visualizer; or apply the clustering model to the current data, then analyze the resulting clusters in any MineSet visualization or mining tool.

### Column Importance

Column Importance determines how important various attributes are for determining the value of a given label attribute. For example, you can ask MineSet to select automatically the best three attributes that help determine whether someone is a good credit risk. The system might select income, own-house, and car-cost. These attributes can then be used to configure various visualizers.

Column Importance has an advanced mode that provides additional capabilities. First, it lets you determine how important each of the attributes is. (For example, you could determine that both income and salary are similar in importance in determining credit risk. Although income might be slightly better in determining importance, you might prefer to use salary because it is easier to obtain.) Second, once you explicitly choose an attribute, you can determine what other attributes are important in conjunction with it. (For example, if you have chosen salary rather than income, house-cost might become more important than own-house, and income would have a very low importance.)

### Decision Table Inducer and Classifier

The Decision Table Classifier classifies data by making a series of consecutive decisions leading to the classification based on a record's attributes. It can be used to predict events such as whether a bank customer is likely to default on a loan, or a homeowner is likely to refinance their mortgage.

The Decision Table Inducer creates a Decision Table Classifier from the data. Attributes are tested to classify the data, and you have the option to set the order in which the tests are run as well. The resulting Decision Table Classifier can be viewed using the Decision Table Visualizer, so you can simultaneously explore multiple attribute tests, two at a time.

### Decision Tree Inducer and Classifier

The Decision Tree Classifier classifies data according to a set of attributes by making a series of decisions based on those attributes. Applying this classifier to determine the profile of someone with credit worthiness, for example, a decision tree might determine if someone who owns a home, owns a car that cost between $15,000 and $23,000, and has two children, is a good credit risk.

The Decision Tree Inducer generates a Decision Tree Classifier, the structure of which is displayed using the Tree Visualizer, each decision being represented by a node of the tree. The graphical representation helps you understand the model, as well as gives valuable insight into the data, by using visual searching and filtering.

### Evidence Inducer and Classifier

The Evidence Classifier classifies data by examining the probabilities of a specified result occurring based on a given attribute. For example, it might determine that someone who owns a car that cost between $15,000 and $23,000 has a 70% chance of being a good credit risk, and a 30% chance of being a bad credit risk. The classifier predicts the class with the highest probability based on a simple probabilistic model.

The model is displayed using the Evidence Visualizer, which shows pie charts illustrating the different probabilities. This graphical representation can help the user understand the classification algorithm, as well as providing valuable insights into the data and answering "what if" questions.

## Option Tree Inducer and Classifier

The Option Tree Classifier classifies data using a technique similar to the Decision Tree Classifier. Unlike decision trees, option trees can contain special option nodes, which allow the classifier to consider the influence of splitting on multiple attributes simultaneously. For example, an option node in an option tree built to identify a car's country of origin might choose miles per gallon, horsepower, number of cylinders, and weight as informative attributes. In a decision tree, a node can choose at most one attribute for consideration at a time. In an option tree, the results of all options are "voted" when performing classification. Option trees are often more accurate than decision trees; however, they generally are much larger.

The Option Tree Inducer generates an Option Tree Classifier from a training set in much the same way that the Decision Tree inducer generates a Decision Tree. The induced option tree is displayed using the Tree Visualizer. This visualization helps you understand the classifier, and provides insight into which attributes are important in determining the value of the label.

## Regression Tree Inducer and Regressor

The Regression Tree Regressor predicts continuous attributes, in the same the way that the Decision Tree and Option Tree Classifiers predict discrete attributes. While a classifier predicts an event, such as whether a customer will churn (leave you) or not, a regressor predicts specific numerical values, such as the profit margin for a business for the next financial quarter.

The Regression Tree Inducer builds a Regression Tree Regressor model from your data. As with Decision and Option Trees, this model can be viewed and analyzed using the Tree Visualizer, so you can understand the basis from which its predictions are made.

## Cluster Visualizer

The Cluster Visualizer displays statistics about the clusters or groups that are generated by the clustering mining tool. It places these statistics side-by-side with those for the entire data set, so that you can see which features make each cluster unique.

The Cluster Visualizer places the attributes in the display in the order of importance for understanding the clustering. When you select one particular cluster, Cluster Visualizer produces an ordering which is the most useful for discriminating between that cluster and the remainder of the data set.

## Decision Table Visualizer

The Decision Table Visualizer allows you to view the distribution of data from a discrete column at multiple levels of a hierarchy. For example, you can examine the profitability of a business along dimensions of product class, geography, sales promotions and sales-representative compensation plan. The Decision Table Visualizer distributes the data two attributes at a time, allowing you to drill-down to further pairs of attributes at each level.

The Decision Table Visualizer explores the results of the Decision Table Inducer, so that the discrete column you examine is the label that the inducer classifies. When this is done, the Decision Table Inducer arranges the attributes to determine which pair to display first, and how to drill down from that top level to subsequent levels.

## Evidence Visualizer

The Evidence Visualizer visually represents the model generated by the Evidence Classifier. It initially shows cake charts that represent how the various attributes contribute to the decision, and allow “what-if” analysis.

## Map Visualizer

The Map Visualizer lets you visualize data relationships that exist across geographically meaningful areas. For example, you can visualize different areas of a country, showing the relative impact of a marketing program. The Map Visualizer’s drill-down capabilities let you focus on designated regions and perform a more detailed analysis in smaller geographical elements. One application might be analyzing how one or more products are being sold across different geographies. A powerful animation feature, coupled with a capability to connect different views of the same or related data, permits fast comparisons and difference analyses. This tool lets you visually examine patterns in your data that are difficult to detect when that data is shown in a tabular, two-dimensional form.

## Record Viewer

The Record Viewer lets you view the data in the current table in a row/column spreadsheet-like tool.

## Rules Visualizer

The Rules Visualizer visually represents the model of the Association Rules Generator mining tool. It provides detailed data analysis that lets you examine relationships across data elements in new ways. In doing so, you might discover relationships that significantly differ from what you might have expected; this, in turn, can lead to important discoveries about your data or the processes behind that data. This tool's visualization capabilities let you discover additional patterns of co-occurrence between these data elements. For example, you can use the analysis of products sold during the last sales promotion to guide your advertising campaign for the next sales period. The Rules Visualizer's high performance would let you analyze the results from today's sales data in time to alter the advertising campaign for the future.

## Scatter Visualizer

The Scatter Visualizer lets you examine the behavior of data across eight different dimensions. The data is shown in a grid representing up to three dimensions. Extra dimensions can map to the size, color, and label of each displayed entity. Two further independent dimensions can be assigned as dynamic dimensions. A slider can be used to select specific values along those dimensions, or a path can be traced through those dimensions, for animation. During the path traversal, the display changes automatically to reflect the change in the independent variables.

## Splat Visualizer

The Splat Visualizer produces 3D plots of very large data sets. Instead of showing individual data points, it renders the density of data using varying opacity. It has many of the same features as the Scatter Visualizer.

## Statistics Visualizer

The Statistics Visualizer computes and displays summary information for the current dataset (maximum, minimum, median, standard deviation, distinct values, and quartiles).

## Tree Visualizer

The Tree Visualizer helps you analyze data that has hierarchical relationships. It provides an interactive “fly-through” capability for examining relationships among data at different hierarchical levels. For example, the Tree Visualizer can be used to examine a company’s product line, graphically displaying each product’s contribution to the company’s total revenue. Each branch of the hierarchy displays information at increasing levels of detail, breaking revenues down by product lines and, eventually, individual products. Another example of using the Tree Visualizer is to show company sales revenue, displaying a company-wide total as well as sub-totals at regional and other levels. The fly-through capability in the Tree Visualizer lets you rapidly reposition your view of the data. The Tree Visualizer’s filtering and searching capabilities let you focus on specific data elements and queries.

The Tree Visualizer is also used to view the resulting models of the Decision Tree and Option Tree Classifiers, and the Regression Tree Regressor; with each decision being represented by a separate node in the tree. Each node also contains bars showing how the data is modeled based on the decisions up to that point (for example, 73% of people who own a home and have two children are good credit risks, while 27% are not).

## Basic Tool Execution Scenario

Each of the MineSet tools is started, configured, and run in a consistent manner. The sequence of actions you follow at your MineSet client and at the MineSet server is shown schematically in Figure 1-1. A description of the steps inherent in this figure follows.

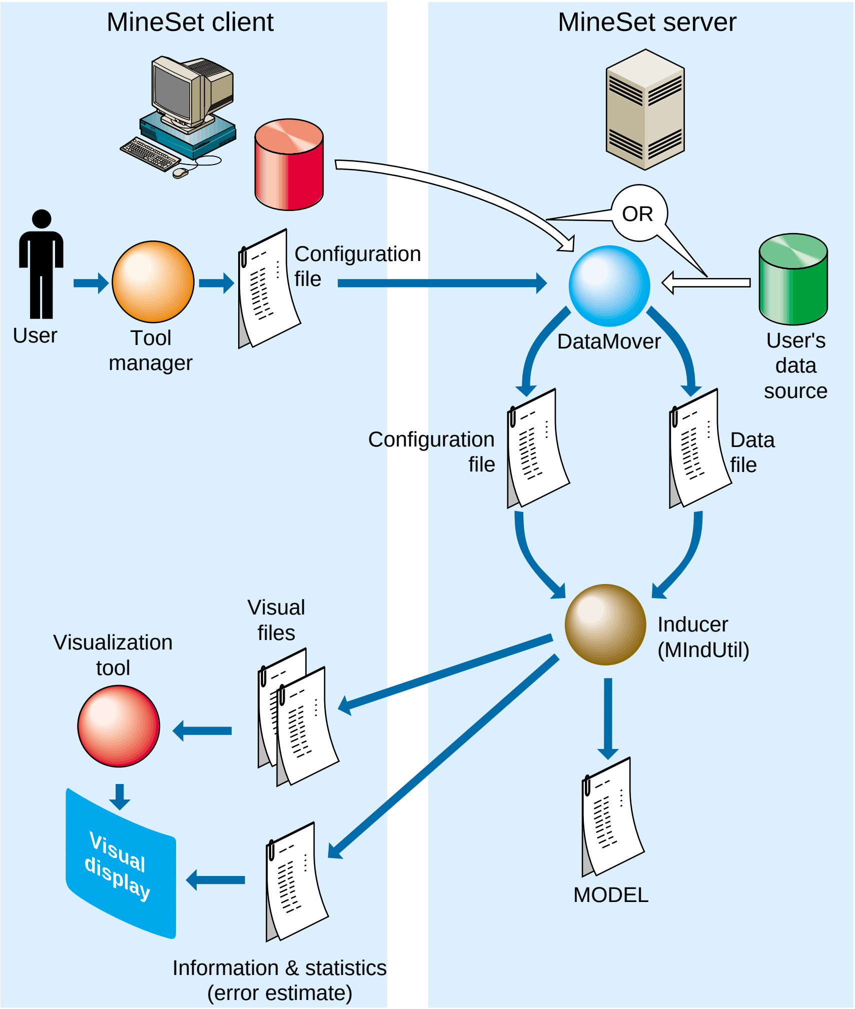


**Figure 1-1** Tool Execution Sequence

The following steps describe a “typical” interaction with a MineSet tool, and the sequence of the tool’s actions. Depending on your requirements, some steps might be skipped (for instance, if the data and configuration files have been generated in a previous work session).

1. Start the Tool Manager, which is the graphical interface for generating and specifying the configuration file, data file, and tools to be used. The Tool Manager runs on your MineSet client.
2. The Tool Manager opens a network connection to the DataMover, which runs on the MineSet server, which in some cases may be the same as your client workstation, and in others is a separate machine.
3. Use the Tool Manager to specify
   - the database and table, or a binary or ASCII flat file containing the data on either the client or the server
   - which mining or visualization tools are to be applied
   - how that data is to be displayed, through tool options
   - a session file to save the history of your work

   Information retrieved via the DataMover is used to guide this interaction. As a result, the Tool Manager generates a configuration file. This file contains the user-defined parameters that determine the execution of the following steps.
4. The Tool Manager transmits a copy of the configuration file from step 3 to the DataMover. The DataMover processes the file by
   - accessing the database or flat file
   - performing the specified data transformations
   - running the mining tools when requested
   - generating the visualization files when requested

   These visualization files consist of your data in a specific format readable by the MineSet tool. Then a copy of these visualization files is transferred to the MineSet client.
5. The Tool Manager invokes the appropriate MineSet visualization tool.
6. The tool accesses the visualization files and displays the data.
7. If you generated a model, that model can be applied to additional data (see Figure 10-5).

**Note:** The MineSet client and server can run on different machines, using a network to communicate. Because network bandwidth is often scarce, you should be cautious about transferring large files between client and server regularly. If you are doing mining operations on a large database or file, you can achieve greater efficiency by storing that file on the server, where the DataMover runs, rather than on the client.

*Chapter 2*

# Setting Up MineSet

This chapter describes how to set up MineSet, which requires configuring the DataMover. The configuration has two parts:

- configuring the user's account on the server (optional), and
- a global configuration, which usually is done by the system administrator

Parallelization is offered through the multiprocessor (n32) version of MineSet only. The DataMover is a process that runs on the server, although it is not directly accessible to users. The DataMover provides access to databases and data stored in flat files, and transforms data for the mining and visualization tools. The last section of this chapter describes how to load sample datasets into the supported relational databases.

## Configuring the DataMover Server

In order to use the MineSet tools, two configuration files must be created on the server: one by you, the other by the system administrator.

### The User Configuration File

**Note:** You must have a UNIX account on every server you want to access.

The DataMover creates files on the server machine on behalf of each user. The DataMover configuration file, *.datamove*, lets you control where these files are created and whether different classes of files are saved or discarded. This file is located on the server, in your home directory. A sample *.datamove* file called *datamove.sample* is located on the server, in the */usr/lib/MineSet/datamove* directory.

If the *.datamove* file is absent, or if a particular entry is not present in the *.datamove* file, the DataMover uses a default value for that entry.

Each entry in the DataMover's configuration file must be on a separate line. For example:

```
file_cache = directory_name
```

where *file_cache* specifies the location in which the DataMover stores its output data files and models resulting from mining algorithms. If the *file_cache* directory does not exist, the DataMover attempts to create it on its first invocation. The default *file_cache* directory is *./mineset_files/%U*. The *%U* is a wildcard that is filled in with the user's login name on the client machine. This is useful in reducing contention if many users want to log in to a common account on the server. If multiple sessions were simultaneously connected to the same *file_cache* directory, they could overwrite each other's server files, causing incorrect and unexpected results. To prevent this, DataMover maintains a lock at the *file_cache* directory level. The second and later attempts to connect to a particular *file_cache* directory result in failure and an error message. The user can recover from such a failure by killing one of the DataMover's attempts to connect to a given file in the cache directory.

The *file_cache* should be a directory in a file system with sufficient room to hold all of a user's output and temporary files. DataMover will create this directory if it doesn't already exist. These are deleted when the DataMover no longer needs them, unless one of the following **keep** options is set:

```
keep_client_upload
keep_client_download
keep_classifier_files
keep_classifier_options_files
keep_mlc_input
use_ascii_mlc_input
```

Each of these entries is described below.

```
keep_client_upload (default no)
```

Keep files uploaded from the client for processing. If kept, they will be in the *client_upload* subdirectory.

```
keep_client_download (default no)
```

Retain on the server a copy of data files and visualizations after they are downloaded to the client. If kept, the files will be in the *client_download* subdirectory.

```
keep_classifier_files (default yes)
```

Keep the persistent classifiers (decision trees and so forth) generated by mining operations. The tactic is generally useful.

```
keep_classifier_options_files (default no)
```

Keep the options file that is used when generating, or inducing the classifier. This tactic is not useful. If kept, the files will be in the *mlc_work* subdirectory.

```
keep_mlc_input (default no)
```

Keep input files used for mining (MIndUtil or associations) operations. If kept, the files will be in the *mlc_work* subdirectory.

```
use_ascii_mlc_input (default no)
```

Normally the DataMover creates MineSet binary files for MIndUtil input. If this option is set, create ascii files instead.

```
aggregation_memory_limit (default 2147483647)
```

Memory limit (in bytes) for aggregation operations. This can be no larger than the system-wide limit set in the *dm_config* file.

```
optimize_history=yes
```

The DataMover is able to rewrite histories to remove redundant computations. The *optimize_history* parameter controls whether or not to do this. Since this rewriting can speed up processing considerably, it is normally turned on.

## File Handling

A file in the *file_cache* directory is the result of a successful operation. If an operation returns an error (that is, Tool Manager reports a message beginning "fatal error on server,") nothing should be changed in the *file_cache* directory. Two examples help illustrate the point:

- Example 1: A user's *file_cache* directory contains the files *cars.data* and *cars.schema*, both the result of a previous database query. The user then selects the same table, and sets the output to *server_file*, filtering for examples with mpg>55. Since no records in the dataset have mpg values this high, when the history executes, it returns no rows, which is flagged as a fatal error. After this happens, the user's *file_cache* directory will still contain the old *cars.schema* and *cars.data* files.
- Example 2: A user's *file_cache* directory contains the files *cars.data* and *cars.schema*, both the result of a previous database query. The user then selects the same table, and sets the output to a visualization. The operation completes and the visualization launches successfully. Once again, the user's *file_cache* directory still contains the old *cars.schema* and *cars.data* files. The *file_cache* directory is not updated unless the user specifically chooses *server_file* as the output.

## Mandatory Configuration File

If you are using relational databases, the MineSet DataMover server must be configured to find information in the databases. The DataMover works with Oracle® versions 7.2 or later, INFORMIX®, and Sybase®.

The DataMover server reads the */usr/lib/MineSet/datamove/dm_config* file during start up. This file is not created by *Inst* during installation. It must be created by the system administrator, who must log in as root to edit this file. It can be created via an editor such as jot, vi, or Emacs. An example file can be found in */usr/lib/MineSet/datamove/dm_config.sample*. The format of this file is as follows:

```
Oracle {
"ORACLE_SID", "ORACLE_HOME";
}

Oracle_Remote {
“DATABASE_NAME”, “ADMIN_DIRECTORY”;
}
Informix {
"INFORMIXSERVER", "INFORMIXDIR";
}
Sybase {
"DSQUERY", "SYBASE";
}
```

Each optional entry describes the databases in use at your site. If your server is not running any databases, that is, you intended to use MineSet with ASCII files only, simply make an empty *dm_config* file.

The line `"ORACLE_SID", "ORACLE_HOME"` is filled in with the specific information and repeated once for each Oracle database to be accessed via the DataMover. `ORACLE_SID` and `ORACLE_HOME` are Oracle specific parameters defining an Oracle instance.

The `Oracle_Remote` section is for accessing remote Oracle databases via SQL*NET V2. The `DATABASE_NAME` entry is a logical name for the remote database, as defined in a *tnsnames.ora* file. The `ADMIN_DIRECTORY` entry is where DataMover searches for the *tnsnames.ora* file. This file is described in Oracle’s SQL*NET documentation. Remote access to databases is described in more detail in “Using MineSet to Connect to Remote Databases” on page 58.

Each line in the `Informix` section defines a database server that, in turn, can contain several databases. The server is checked at runtime to determine which databases it contains, so there is no need to record the individual databases in the *dm_config* file. The first entry is the INFORMIX server (corresponding to the *INFORMIXSERVER* environment variable), and the second is the INFORMIX directory (corresponding to the *INFORMIXDIR* environment variable).

Each entry in the Sybase section defines a database server (or, in Sybase terminology, an SQL Server™). The first entry is the Sybase SQL Server name (corresponding to the *DSQUERY* environment variable); the second is the Sybase home directory (corresponding to the *SYBASE* environment variable).

An example configuration file might be as follows:

```
Oracle {
"v73", "/usr/people/oracle/v73";
"wrhse", "/opt/oracle";
}

Oracle_Remote {
   “lifeseq”, “/usr/lib/MineSet2/datamove/”;
}
Informix {
"learn_online", "/u5/informix";
}
Sybase {
"MINESET", "/usr/sybase/10.0.2.4";
}
```

This configuration file lets the DataMover access:

- three Oracle databases, one named *v73* (installed in */usr/people/oracle/v73*), another named *wrhse* (installed in */opt/oracle*), and a remote database named *lifeseq*,
- an INFORMIX Server;
- and a Sybase SQL Server.

Each of the INFORMIX and Sybase servers can, in turn, contain multiple databases.

For Sybase, DataMover uses vendor-supplied shared libraries as its connection to the databases. One of the purposes of the *dm_config* file is to specify where DataMover must look for its shared libraries. DataMover looks in the *$SYBASE/lib/* directory for the following shared libraries: *libct.so*, *libcs.so*, *ibcomn.so*, *libintl.so*, *libtcl.so*, *libinsck.so*.

## Using MineSet With Existing Data Files

Sometimes it is convenient to use MineSet with data that is already stored as a file, but requires further processing before it can be mined or visualized. In this case, the data file can be made available (with a modest effort) to the Tool Manager/DataMover.

First, the data file must be in a tab-delimited format, with the same number of fields in each line. A numeric or string field with a single “?” character appearing between delimiters is loaded as a Null value.

For a detailed discussion of null values, refer to Appendix J, "Nulls in MineSet."

The contents of the data file must be described to Tool Manager/DataMover via a file with the *.schema* extension. The format of the *.schema* file is shown next:

```
#
#  A line beginning with a "#" is a comment
#
input {

#  The first line lists the data file which is described.  It
#  must be a simple filename, not a path.

     file "carmodels.data";

#  Fields are listed left to right in the line, legal
#  types are float, double, int, string, date, fixedString and
#  dataString
#  Be sure to end every line with a semicolon ";"

     float mpg;
     int cylinders;
     float cubicinches;
     int horsepower;
     int weightlbs;
     double timeaccelerate;
     date when_introduced;
     string origin;
     fixedString(3) manufacturer_code;
     dataString model;
}
```

The schema and data files must be located in the same directory. If you prepare a dataset in this fashion on the client machine, it can be opened with the Tool Manager's *Find File* dialog. If the file requires any additional processing, it is copied to the server. Sometimes this is not convenient, especially if the file already exists on the server, or is large. In this case, the *.schema* and *.data* files must be copied (or symbolically linked) into your *file_cache* directory on the server. The directory used as the file cache is specified in your *.datamove* file; the default is *./mineset_files/%U*, where *%U* becomes your login name on the client machine.

For a more extended description of MineSet *.schema* files see Appendix A.

## Using MineSet to Connect to Remote Databases

Sometimes it might not be feasible to install DataMover on the machine running the database server. In this situation, DataMover can be installed on an intermediate server, and DataMover then can use the database vendor's networking facility to connect to the remote database. (This sometimes is referred to as a three-tier architecture.)

### Oracle

MineSet supports two ways to access remote Oracle databases:

- The remote database is specifically mentioned in the *dm_config* file. For this method, add entries to the `Oracle_Remote` section of the *dm_config* file, as described in the "Mandatory Configuration File" section, above. Every remote database named in the *dm_config* file must be defined in the *tnsnames.ora* file. This file can be manually edited, or, more commonly, generated automatically by a network administration tool provided by Oracle. If this method is chosen, the only Oracle-specific file needed on the DataMover server is *tnsnames.ora*; in particular, Oracle need not be installed on this machine.
- A local Oracle install is used as a gateway to a remote database. In this case, the *dm-config* file requires an entry for the local Oracle install, with `ORACLE_HOME` and `ORACLE_SID`. This entry must be in the `Oracle`, not `Oracle_remote` section. Entries for any remote databases must be added to the *$ORACLE_HOME/network/admin/tnsnames.ora* file of the Oracle install on the intermediate server.

  Then, when users want to log in to user "system", password "manager" at database "remotedb", they must provide the name of the intermediate server for the Tool Manager "Log on to server..." dialog and select the intermediate server's Oracle database. When logging in to the database, use **`system@remotedb`** for the database username, and **`manager`** for the password. (The added **`@remotedb`** specifies that Oracle must use SQL*Net™ to connect to the remote database, instead of using a local connection.)

Operating across SQL*Net is substantially slower than a local connection, especially for queries that return a large amount of data. If possible, install DataMover on the same machine as the Oracle server.

### Sybase

A Sybase installation is required on the intermediate DataMover server; this Sybase installation need not be running an active database, but it is needed for access to the shared libraries and the *interfaces* file.

In order to access the Sybase SQL server running on the remote machine, the *interfaces* file on the DataMover server machine must have an entry for this Sybase SQL server. Please refer to your Sybase manuals for the procedure for creating such entries. Also, the name of this Sybase SQL server on the remote machine must be included in the *dm_config* file on the intermediate DataMover server machine.

Once this setup is done, access to the Sybase SQL server on the remote machine is handled transparently. The user can choose it and access data from it just like any other database source, using the panels from the Tool Manager.

## Loading Sample Datasets

This section describes how to load the sample datasets included with the MineSet distribution into one of the supported relational databases.

Installed on the server in */usr/lib/MineSet/DBexamples* are

- all the sample data, along with a brief description of what it contains.
- directions on how to load the data using the provided scripts.

Load the sample datasets into a database that has been set up on your server. The data and these directions (*README.server*) are installed in */usr/lib/MineSet/DBexamples* on the server.

The */usr/MineSet/DBexamples* directory contains scripts for loading the complete set of data files into one of the supported databases. To load the complete set of data, run one of the following loader scripts, depending on which database you have. (This assumes your database and environment are already set up.)

```
sh load_all_Oracle.sh <userid> <passwd>

sh load_all_Sybase.sh <userid> <passwd>
```

If you are going to work with an INFORMIX database, use the `dbaccess` interface to select

```
create_all_Informix.sql
```

followed by

```
load_all_Informix.sql
```

### Loading Individual Datasets

Alternatively, you can load, or reload, the sample data separately. Each data directory in */usr/lib/MineSet/DBexamples* on the server contains files necessary to load the data into any of the supported databases. These files are:

*README* - explains the data

**.sql* - sets up an Oracle table
**.ctl* - control file for loading into Oracle

**_syb.sql* - sets up a Sybase table
**.bcf.fmt* - Sybase format file

**_inf.sql* - sets up an INFORMIX table
**_load.sql* - loads the data into the INFORMIX table

In the **.ctl* file, the separator is declared in the line

```
" fields terminated by X'20'  "
```

The separator is specified in ASCII hexadecimal; thus:

`X'20'` is used for ‘ ’
`X'2c'` is used for ‘,’
`X'09'` is used for ‘\t’

### Loading Into Oracle

Perform the following steps on the server with an Oracle database:

1. Ensure the following environment variables are set correctly:

   ```
   ORACLE_HOME
   ```

   ```
   ORACLE_SID
   ```

2. Type

   ```
   sqlplus <userid>/<passwd>
   SQL> @<dataset>.sql
   ```

   Where *dataset* is the name of the dataset being loaded, and *userid/passwd* are your assigned username and password for the Oracle database.

   To delete an already existing table, type

   ```
   SQL>  drop table <dataset>;
   ```

3. Type

   ```
   sqlload control = <dataset>.ctl userid = <userid>/<passwd>
   log = /tmp/<dataset>.log  direct = true
   ```

4. Check the resulting *dataset.log* to ensure the data was loaded correctly.

### Loading Into Sybase

Perform the following steps on the server with a Sybase database:

1. Ensure that the following environment variables are set:

   ```
   SYBASE
   DSQUERY
   ```

2. To create the table, type

   ```
   isql -U<userid> -P<passwd> -i <dataset>_syb.sql
   ```

   Where *dataset* is the name of the dataset being loaded, and *userid/passwd* are your assigned username and password for the Sybase database.

   To delete an already existing table, type

   ```
   isql -U<userid> -P<passwd>
   drop table <dataset>
   go
   ```

3. To load the data, type

```
bcp <dataset> in <dataset>.data -U<userid> -P<passwd> -f
<dataset>.bcp.fmt
```

where *dataset* is the table name (created using *<dataset>_syb.sql)*, `in` means "load into the dbms," *<dataset>*`.data` refers to the name of the ASCII data file, and **-f** points to the already-created format file. (When reading in from a file, the data types are character.)

#### Loading Into INFORMIX

Perform the following steps on the server with an INFORMIX database:

1. Ensure the following environment variables are set:

```
ONCONFIG
INFORMIXSERVER
INFORMIXTERM
```

2. To create the table, type

```
dbaccess
```

3. If necessary, log into the appropriate database.
4. Choose *Query-language*, then choose the appropriate database from those listed.
5. Choose *<dataset>_inf.sql*, and run it.
6. Choose *<dataset>_load.sql*, and run it (where *<dataset>* is the name of the dataset being loaded).

*Chapter 3*

# The Tool Manager

This chapter discusses the functions of the Tool Manager, which is the graphical user interface (GUI) that lets you specify data and configuration information for the MineSet tools in this package. It provides an overview of this interface, then describes every component of each panel that this interface displays for all MineSet tools.

**Note:** Any screens dedicated to a specific tool are discussed in the chapter for that tool; for example, the screen for specifying the Tree Visualizer's configuration file is discussed in Chapter 5, "Using the Tree Visualizer."

## Overview

The Tool Manager is the initial graphical user interface (GUI) you use for most of your interactions with the MineSet components. With Tool Manager you can select an existing data source, transform or analyze that data, and visualize the results using any of the MineSet individual tools. You can step through the process in these sections:

- "Connecting to an Existing Data Source"
- "Transforming the Data"
- "Visualizing the Data on the Screen"

**Note:** The Tool Manager generally does not support data files not created by the Tool Manager without some manual work to make them compatible.

## Connecting to an Existing Data Source

You can specify the source of the data as being from a:

- database table
- database SQL query
- file

## Transforming the Data

Often the original data is unsuitable for mining or visualization. It may contain irrelevant or redundant columns, data types that are not applicable for viewing, or inconsistencies that result in unhelpful visualization. You can transform the data with the Tool Manager to display it in a useful form in any of these ways:

- mining tools—finds patterns in data
- binning variables—discretizes column values into groups, such as grouping years by decade
- removing columns—excises unneeded columns to save space
- adding new columns—creates columns that are functions of existing columns
- aggregation—finds the average, sum, min, max, or counts of column values
- filtering—selects a subset of the data based on an expression using column values
- sampling—selects a random subset of the data
- making arrays—takes the values of one column and turns them into an array indexed by discrete values in another column
- distributing columns—makes two or more new columns from a single column of values, distributed by the discrete values of another column

## Visualizing the Data on the Screen

The final step, having transformed the data, is to visualize the results.You can do this in any of these ways; for example you can display the data on the screen as:

- a hierarchy (Tree Visualizer—Option, Decision, Regression)
- a map (Map Visualizer)
- a scatter plot showing relations of numerous independent variables (Scatter Visualizer and Splat Visualizer)
- as associated rules (Rules Visualizer)
- as evidence and probability (Evidence Visualizer)
- as box plots and histograms (Statistics Visualizer and Cluster Visualizer)
- as layered tables or cakes (Decision Table)

With Tool Manager you can map data values to specific visual elements on the screen such as:

- colors
- bars
- heights

Finally, Tool Manager lets you control those options not related to data, including:

- background colors
- grid spacing
- label sizes

## Starting the Tool Manager

You can run the Tool Manager in two modes:

- interactive mode—the Tool Manager provides windows, menus, buttons, and so on, to let you access, mine, and visualize your data. Interactive mode also lets you save a description of your actions to a "session file" for future use.
- batch mode—the Tool Manager performs all the actions described in a session file without bringing up windows. For example, batch mode is useful for lengthy computations that need to be done every night, so that the data can be fully prepared each morning.

There are three ways to start the Tool Manager in interactive mode:

- Double-click the MineSet icon, which is in the Applications or the MineSet page of the icon catalog. The Tool Manager starts with the same configuration used in the last Tool Manager session.
- Double-click an icon representing a session file saved from a previous invocation of the Tool Manager. This starts the Tool Manager with that session file.
- Start the Tool Manager from the UNIX shell command line by entering this command at the prompt:

  ```
  mineset [ sessionFile ]
  ```

  Here, `sessionFile` is optional and specifies the name of the session file to use. If you do not specify a configuration file, MineSet starts up with the configuration most recently used.

To start the Tool Manager in batch mode, enter this command at the UNIX shell prompt:

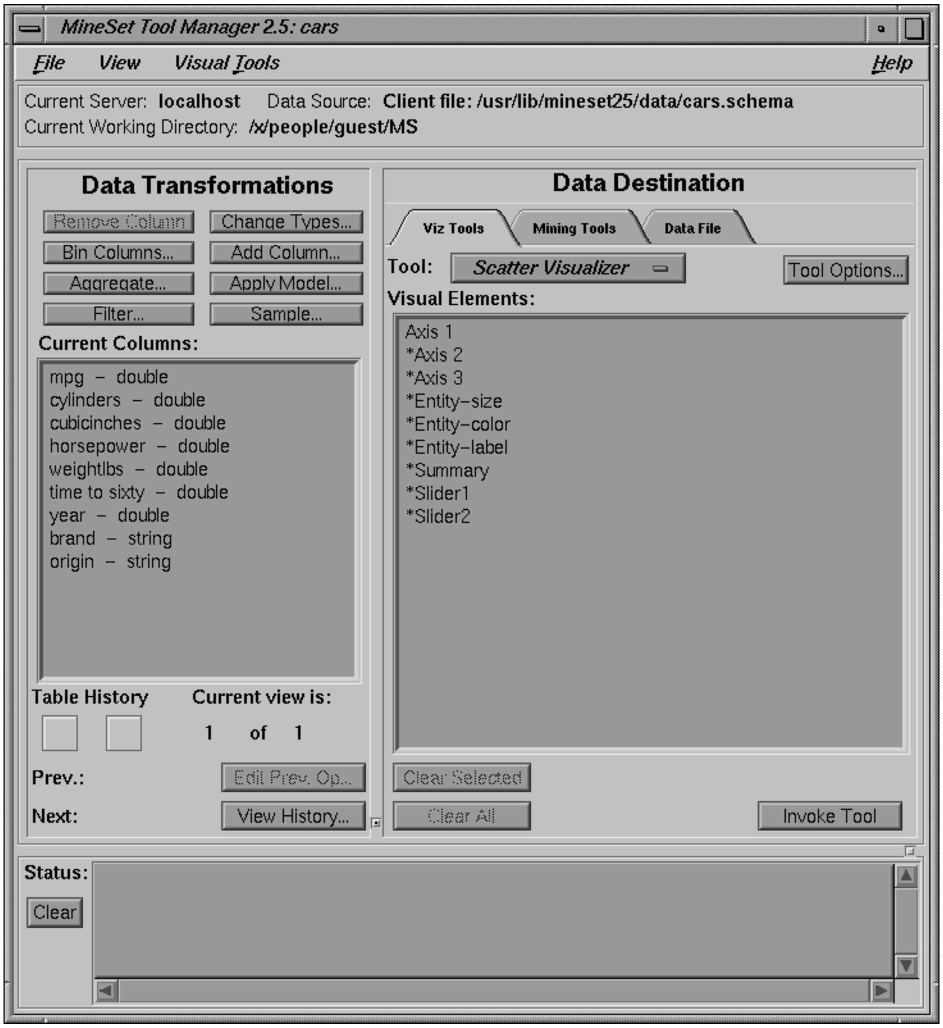
```
mineset_batch [-s serverPassword -d databasePassword] sessionFile
```

The **-s** and **-d** options allow you to specify the password for logging into the server and database respectively. If you do not specify these options, *mineset_batch* will ask you to type in the passwords, thus these options are useful when running *mineset_batch* from a shell script. To specify that there is no password for either the server or database, use **-s** or **-d** followed by two double quotes, that is,

```
mineset_batch -s "" -d "" foo.mineset
```

If you specify one of the two passwords, you must specify both.

Figure 3-1 shows the Tool Manager's startup window.



Current Server: **localhost** Data Source: **Client file: /usr/lib/mineset25/data/cars.schema**
Current Working Directory: **/x/people/guest/MS**

**Current Columns:**

mpg – double
cylinders – double
cubicinches – double
horsepower – double
weightlbs – double
time to sixty – double
year – double
brand – string
origin – string

**Current view is:** 1 of 1

**Tool:** *Scatter Visualizer*

**Visual Elements:**

Axis 1
*Axis 2
*Axis 3
*Entity–size
*Entity–color
*Entity–label
*Summary
*Slider1
*Slider2

**Figure 3-1** The Tool Manager Startup Window

This window consists of two panels related to the specific dataset and tool chosen, and two information sections. Specification of servers and data sources is done via popup dialogs accessible from the File menu.

The panels and information sections are

- *Data Transformations*, which lets you modify the data from your data source.
- *Data Destination*, which lets you create visualizations based on your data, save the data to a file, mine the data for association rules, create classifiers based on the data, or find important columns in the data.
- The top panel, which provides information on the currently selected data source.
- The bottom panel, which contains a stream of information on the status on certain operations.

The following sections describe each panel of the main Tool Manager window.

## Choosing a Data Source

Data sources are selected using the first set of menu items in the File menu.

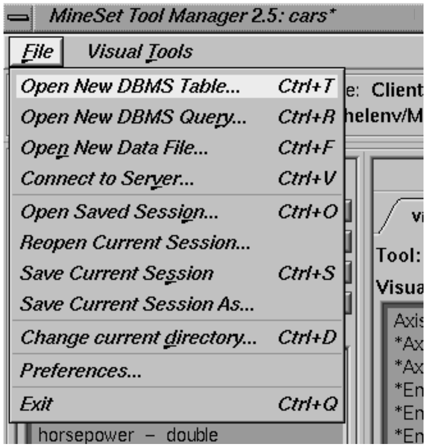

MineSet Tool Manager 2.5: cars*
File
Visual Tools
Open New DBMS Table... Ctrl+T
Open New DBMS Query... Ctrl+R
Open New Data File... Ctrl+F
Connect to Server... Ctrl+V
Open Saved Session... Ctrl+O
Reopen Current Session...
Save Current Session Ctrl+S
Save Current Session As...
Change current directory... Ctrl+D
Preferences...
Exit Ctrl+Q
e: Client
helenv/M
Tool:
Visua
Axis
*Ax
*Ax
*En
*En
*En
horsepower – double

**Figure 3-2** File Pulldown Menu

The first three options in the File menu let you select the data source from a

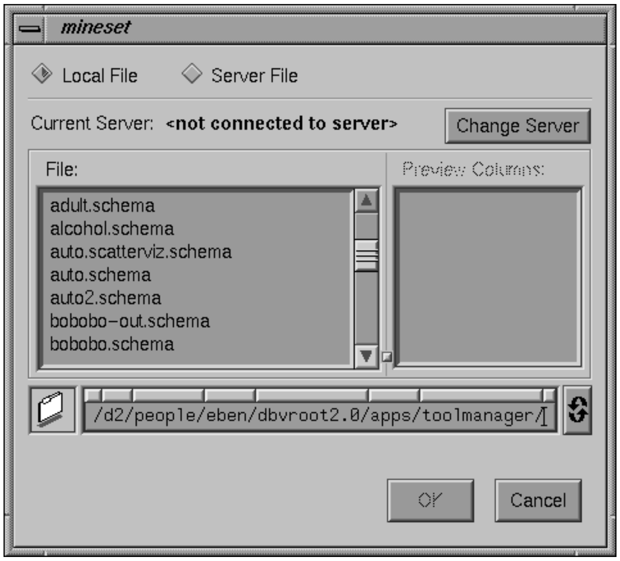
- DBMS Table
- DBMS Query
- Data File

The fourth option, Connect to Server, lets you connect to a server without specifying the data source.

You must connect to a server to get information from a database or mining tool, or to apply transformations to an existing data file. It is not necessary if you plan to visualize an existing client data file without transforming it.

## Choosing an Existing Data File

Use the Open New Data File menu option to work with an existing data file. When you select this option, the dialog in Figure 3-3 appears.



● Local File ○ Server File

Current Server: **<not connected to server>**

adult.schema
alcohol.schema
auto.scatterviz.schema
auto.schema
auto2.schema
bobobo-out.schema
bobobo.schema

/d2/people/eben/dbvroot2.0/apps/toolmanager/

**Figure 3-3** Open New Data File Dialog Box

This dialog box, which is similar to a standard file selection dialog box, provides a toggle at the top to select client versus server files; it also has a label indicating the name of the current MineSet server, and a push button to let you log in to a new server. The radio buttons at the top let you select files on your client machine (in any directory accessible to you) or files that exist in your single cache on the DataMover server, (see "Configuring the DataMover Server" in Chapter 2.)

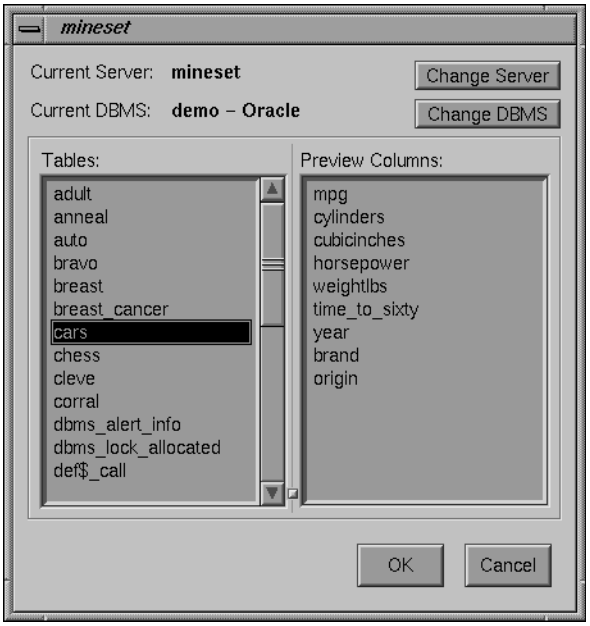
When you select the name of a file from the list in the left window, the columns of that data file are shown in the right window.

When you click the *Change Server* button, a dialog prompts you for a server name, login name, and password to connect to the server (see Figure 3-5).

If you want to access a data file created outside of Tool Manager, you must create a *.schema* file for it. This is a text file containing a configuration "input" section, which gives the name of the data file and describes its layout. The Tool Manager supports input sections similar to those for the Tree Visualizer (described in Appendix B), except that it does not support variable length arrays or the monitor option.

## Choosing a Database Table

Use the Open New DBMS Table menu option to work with tables in a DBMS. Selecting this option causes the dialog box in Figure 3-4 to be displayed.



Current Server: **mineset**

Current DBMS: **demo – Oracle**

Tables:

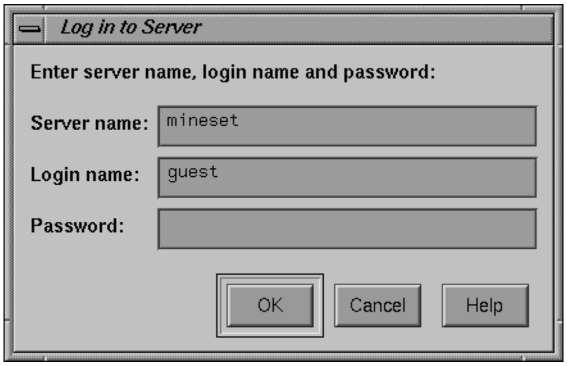
adult
anneal
auto
bravo
breast
breast_cancer
cars
chess
cleve
corral
dbms_alert_info
dbms_lock_allocated
def$_call

Preview Columns:

mpg
cylinders
cubicinches
horsepower
weightlbs
time_to_sixty
year
brand
origin

**Figure 3-4** Choosing New Database Table Dialog Box

The name of the currently selected server appears to the left of the *Change Server* button. If you click this button, the dialog box shown in Figure 3-5 appears. This lets you specify a server name, login, and password.



**Enter server name, login name and password:**

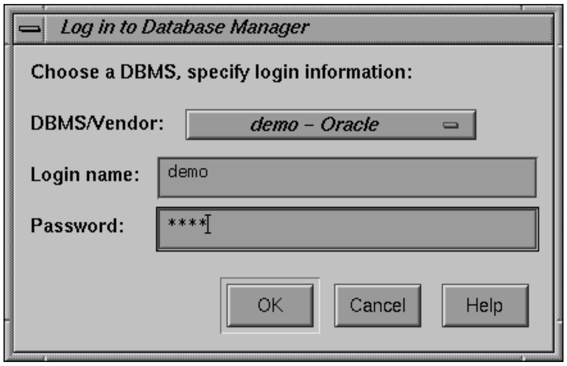
**Server name:** mineset

**Login name:** guest

**Password:**

**Figure 3-5** Specifying Server Name, Login, and Password

Once you have logged in to a server, click the *Change DBMS* button to bring up a dialog box that contains a popup menu listing DBMS names/vendors (see Figure 3-6). Select a DBMS from the menu, and enter the login name and password to connect to the DBMS. Note that the DBMS login and password are usually different from those required to connect to the server.



Choose a DBMS, specify login information:

DBMS/Vendor: demo – Oracle

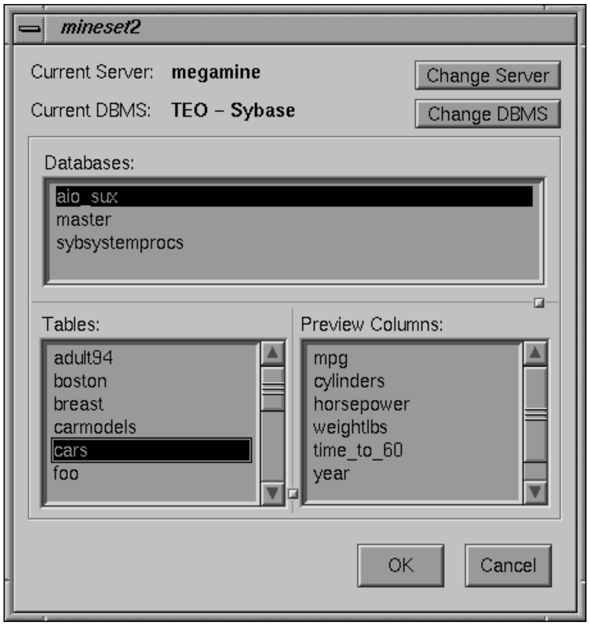
Login name: demo

Password: ****

**Figure 3-6** Sample Dialog Box Listing Available DBMS Names/Vendors

If you have logged on to an Oracle DBMS, the dialog box appears as shown in Figure 3-4, with a list of tables on the left. When you select a table, the columns for that table are shown on the right.

If the DBMS is Informix or Sybase, the dialog box shown in Figure 3-7 appears, with a list of databases for the DBMS. Select a database, and the list of tables in that database are shown.



Current Server: **megamine**

Current DBMS: **TEO – Sybase**

Databases:

- aio_sux
- master
- sybsystemprocs

Tables:

- adult94
- boston
- breast
- carmodels
- cars
- foo

Preview Columns:

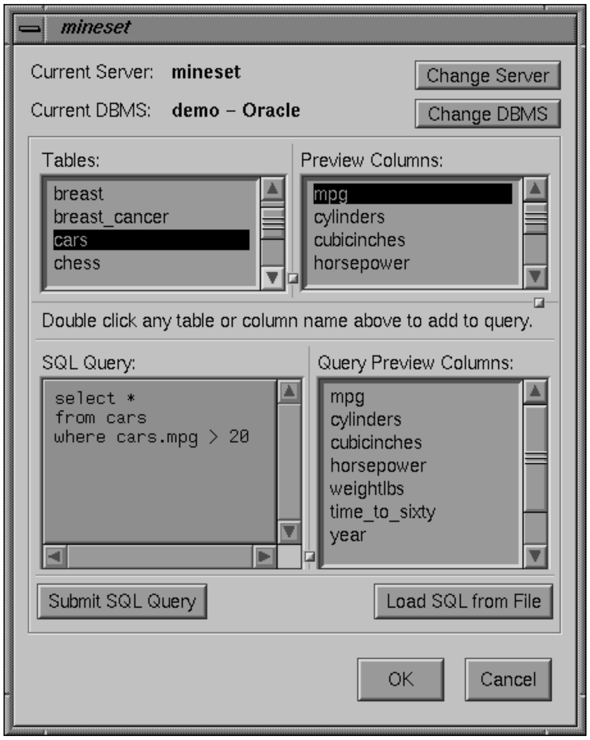
- mpg
- cylinders
- horsepower
- weightlbs
- time_to_60
- year

**Figure 3-7** Dialog Box After Selecting Informix or Sybase DBMS

To use a certain table in the Tool Manager, select the table you want to use and click *OK*.

### Running an SQL Query

Use the Open New DBMS Query menu option to work with tables created via SQL queries against a DBMS. Selecting this option causes the dialog box in Figure 3-8 to appear.



Current Server: **mineset**

Current DBMS: **demo – Oracle**

SQL Query:

```
select *
from cars
where cars.mpg > 20
```

**Figure 3-8** SQL Query Dialog Box

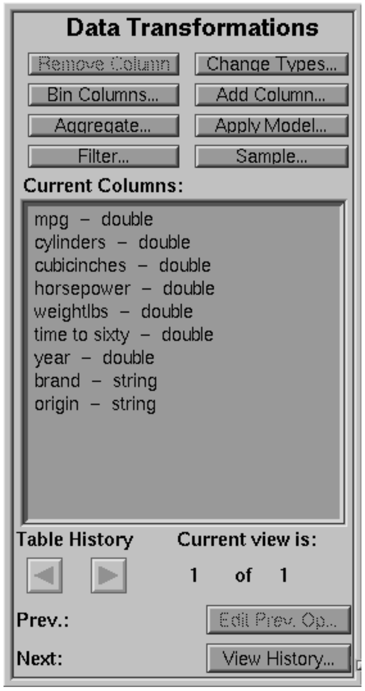
Selecting a server and DBMS in this dialog box has the same effect as selecting those items in the Open New DBMS Table dialog box.

The SQL query is shown in the panel at the lower left. You can enter the query there, or load it from a disk file using the *Load SQL from File* button. The names of tables and columns in the current DBMS are shown to help build queries. To have their names transferred to the SQL query panel, double-click on them.

When you have entered the SQL query, click the *Submit SQL Query* button to send it to the DBMS for execution. The table columns resulting from the query appears on the right.

## Transforming the Data

The Data Transformations panel lets you manipulate the tables with which you want to work. After you have selected a table (via the File menu, described above), its column headings appear in the *Current Columns* window of the Data Transformations panel (Figure 3-9).



mpg – double
cylinders – double
cubicinches – double
horsepower – double
weightlbs – double
time to sixty – double
year – double
brand – string
origin – string

1 of 1

**Figure 3-9** The Data Transformations Panel

The functions of the displayed options are:

- *Remove Column*—lets you delete one or more columns that are not relevant to the current visualization or mining.
- *Bin Columns*—lets you assign each record to a group that falls within a certain range (bin) of column values. For example, an age column may be binned into the ranges (bins): 0-18, 19-25, 26-35, and so on.

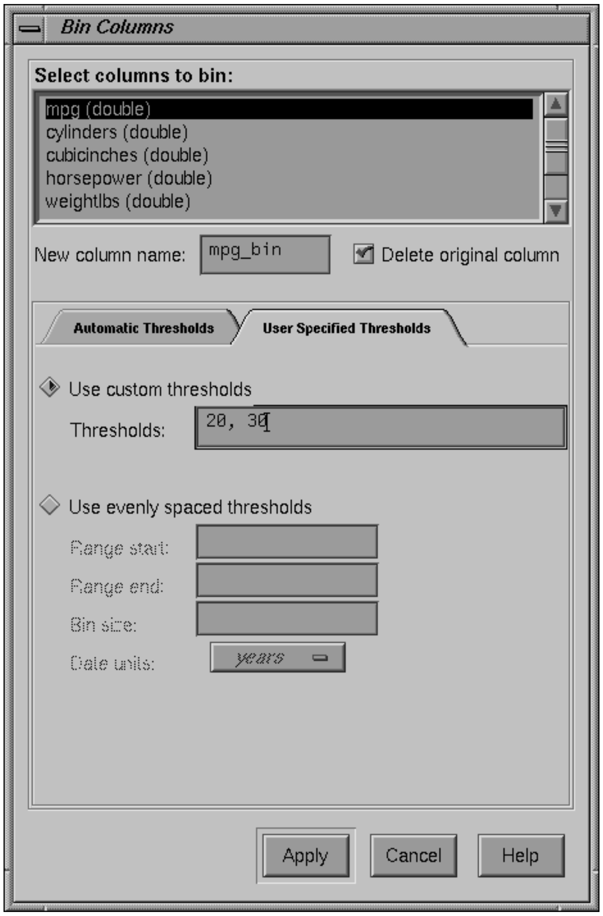
- *Aggregate*—adds columns of records (sum), creates a new column representing maximum or minimum values, or makes an array from a column that is indexed by other columns.
- *Filter*—lets you select a subset of the data based on an expression involving column values, for example, leave only those records in which the age is less than 20.
- *Change Types*—lets you change a column's name as well as its type.
- *Add Column*—lets you add a new column based on a mathematical expression. For example, add a column "minor" based on the column "age," using the expression: "if age is less than or equal to 18 then minor is true; else minor is false."
- *Apply Model*—lets you use a previously created classifier to label new records, to estimate probabilities for label values, to test the classifier on new data, or to backfit data to an existing classifier (see Chapter 10, "MineSet Inducers and Classifiers," for details).
- *Sample*—lets you select a random subset of the data. This is useful for very large data sets.

### The Remove Column Button

*Remove Column* lets you delete columns by selecting the column name or names in the *Current Columns* panel, then clicking this button. The items in the *Current Columns* panel change to show the new table columns. To choose multiple contiguous columns for simultaneous removal, click and drag the mouse over the columns. To choose multiple non-contiguous columns for simultaneous removal, hold down the Ctrl key while selecting the additional columns.

## The Bin Columns Button

Binning lets you sort the information from one or more columns into groups in a new column or columns (for example, with a range of ages, 0-18, 19-25, 26-35, and so on). Click *Bin Columns* to get a dialog box that lets you specify the binning options (Figure 3-10).



Bin Columns

Select columns to bin:

- mpg (double)
- cylinders (double)
- cubicinches (double)
- horsepower (double)
- weightlbs (double)

New column name: mpg_bin

☑ Delete original column

● Use custom thresholds

Thresholds: 20, 30

○ Use evenly spaced thresholds

Range start:

Range end:

Bin size:

Date units: years

**Figure 3-10** Bin Columns Dialog Box

This dialog box lets you

- choose the column that is to be divided into bins
- specify the name of the new column to contain values for the bins
- set bin thresholds, or specify a range with thresholds at regular intervals

To specify binning options for one or more columns, select the column name(s), choose the appropriate options below, and click the *Apply* button at the bottom of the dialog box.

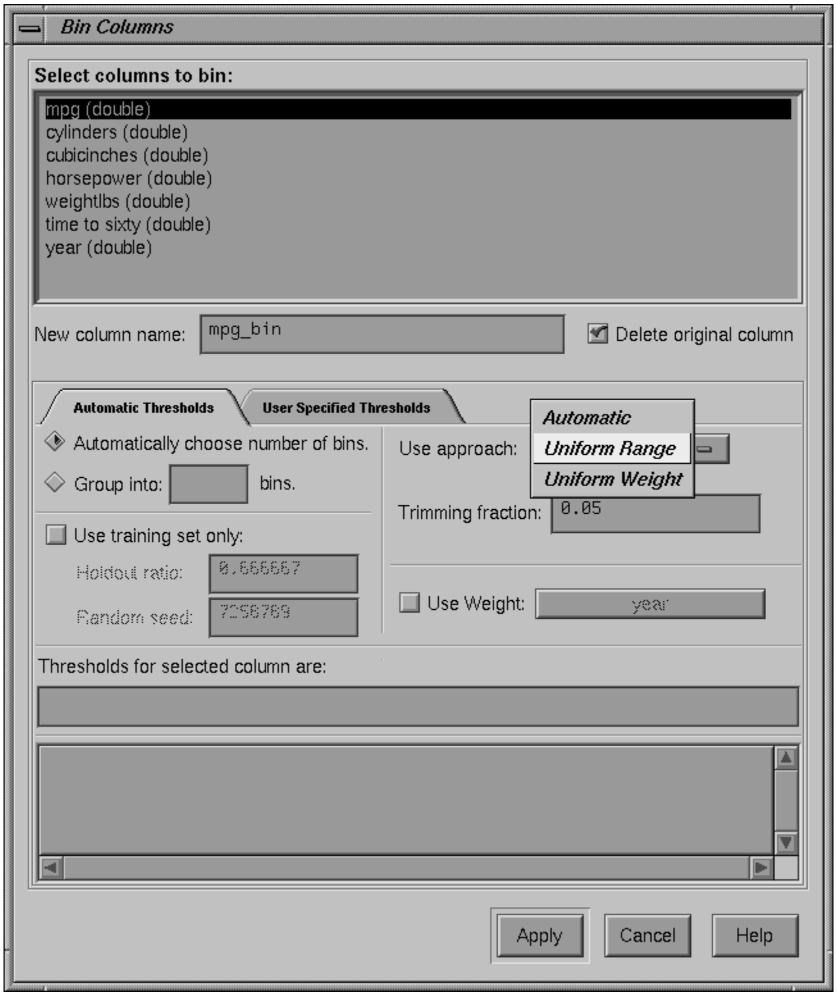
If you select only one column for binning, the name of the resulting binned column appears in the "New column name" box, and you can type in a new name if you like. In the example shown in Figure 3-10, mpg_bin is the name for the new column; in this case, it provides a range of fuel efficiencies. If you select more than one column for binning, New column name stays inactive.

Next to New column name is a check box labeled "Delete original column". When chosen, this option automatically deletes the original column after binning. Click the check box to turn this function on or off.

In the middle of the Bin columns dialogue box are two tabs for choosing Automatic Thresholds or User Specified Thresholds. Choose Automatic Thresholds if you'd like the computer to suggest the bins or User Specified Thresholds if you'd like to specify the thresholds yourself.

### Automatically Computed Thresholds

If you've chosen the Automatic Thresholds tab, the program can use machine learning to suggest bins.



Select columns to bin:

mpg (double)
cylinders (double)
cubicinches (double)
horsepower (double)
weightlbs (double)
time to sixty (double)
year (double)

New column name: mpg_bin

☑ Delete original column

● Automatically choose number of bins.

○ Group into: bins.

□ Use training set only:

Holdout ratio: 0.666667

Random seed: 7258769

Use approach: Uniform Range

Trimming fraction: 0.05

□ Use Weight: year

Thresholds for selected column are:

**Figure 3-11** Binning With Automatically Computed Thresholds

The first choice under Automatic Thresholds is between the *Automatically choose number of bins* and the *Group into: ___ bins* buttons. Click *Automatically choose number of bins* to let the computer decide the best number of bins. If you choose to specify the number of bins, click *Group into: ___ bins*, and type the number of bins you want into the field.

There are three ways to categorize data into bins:

- *Automatic*—you must also select a discrete label. The thresholds are chosen so that the distributions of labels within different bins are as different as possible. This approach continues to create thresholds that split the range until no additional interval is considered significant.

  The "Min weight per bin" text field lets you specify the minimum weight in any bin; this prevents the creation of bins with less weight than the number specified. No interval is split if the two resulting subintervals do not each contain at least the minimum weight you specify. By default, each instance has unit weight. In this situation, specifying the Min weight per bin is the same as specifying the minimum number of instances per bin.

  Rather than specifying the minimum weight per bin, it is possible to have the algorithm set that value automatically. The check box labeled *Auto* causes the algorithm to calculate a value for the minimum weight per bin based on the total weight of the instances: the more total weight, the higher the minimum weight per bin (the relationship is logarithmic).
- *Uniform Range*—the algorithm divides the value range into the specified number of uniformly sized subintervals. The upper and lower bounds for the extreme ranges include any values outside the ranges observed in the data. For example, if the values for an attribute are in the range 3-8, and you specify four bins, the thresholds identified are 4.25, 5.5 and 6.75, corresponding to the ranges:
  - ≤ 4.25
  - > 4.25 to 5.5
  - > 5.5 to 6.75
  - > 6.75
- *Uniform Weight*—the algorithm divides the value range into the specified number of equal weight bins. Unlike Uniform Range, in which thresholds are identified that separate the value range into intervals of equal size, Uniform Weight identifies thresholds that group the instances into subsets of equal weight. By default, each instance has unit weight. In this case, the Uniform Weight approach produces the specified number of bins, each containing an approximately equal number of instances.

Both Uniform Range and Uniform Weight let you specify a trimming fraction, which indicates the fraction of extreme values to be excluded from the value range prior to generating bins. The default trimming fraction is 0.05. This excludes the 5% of the instances with the most extreme values (2.5% with the lowest values in the range, and 2.5% with the highest values in the range). Trimming tends to reduce the influence of outliers on the generation of thresholds.

All of the approaches let you decide whether you want to specify the number of bins or let the algorithm select the number automatically. For the Uniform Range and Uniform Weight approaches, the automatic selection of the bins is based on the number of distinct values: the more distinct values, the more bins are chosen (the relationship is logarithmic).

Typically, all of the available instances are used when identifying thresholds. When binned attributes are later used to induce a classifier, the error estimates for that classifier tend to be overly optimistic. This is because distributional information from the test set was used to identify thresholds. *Use training set only* prevents the binning approaches from looking at the records in the test set when identifying thresholds. This tends to give a more realistic estimate of the classifiers' error rate. *Use training set only* requires the user to specify the same Holdout ratio and Random seed (see “Error Options for Inducers” in Chapter 10) that are used to create the holdout set for estimating classifier error.

The Use Weight menu lets you weight the instances by any numeric attribute. Changing instance weight affects both Automatic and Uniform Weight, but has no affect on the Uniform Range.

If you click *Apply*, the Tool Manager picks bin thresholds and displays them in the “Thresholds for selected column are” text field. The text field at the bottom of the Bin Columns window shows the progress of the binning algorithm and any errors that occur.

### Specifying Thresholds

If you specify your own thresholds (as shown in Figure 3-10), you can choose between *Use custom thresholds* or *Use evenly spaced thresholds* by clicking either button. When you type in the thresholds, you must click *Apply* to make those thresholds effective for the selected columns.

The *Use custom thresholds* text box lets you enter the range criteria. For example, you could enter the numbers 18, 30, 50, 60. This results in the following ranges: 0-18, 19-30, 31-50, 51-60, 61+. Note that you enter only the digits and commas, not the ranges.

To specify equally spaced bins over a range of values, click the *Equally Spaced Bins* button. This activates the three text fields below it. You can type the start of the binning range, the end of the range, and the spacing of the bins, respectively, into these fields. If you are binning a column that is a date, you can specify units of time for the bin spacing (using the "Date units" popup menu under the text fields). This would permit you, for example, to bin a time period into bins of three weeks. Dates entered into these fields must be typed in the form "MM/DD/YY". Possible time units are as follows:

- years
- quarters
- months
- days
- hours
- minutes
- seconds

The *Use custom thresholds* text box accepts dates either in double quotes (as shown below), or without. If you enter dates without quotes, the quotes are added automatically.

```
"1/1/96", "2/1/96", "3/1/96", "4/1/96", "5/1/96", "6/1/96"
```

However, do not put quotes around dates used with *Use evenly spaced thresholds*.

**Note:** If you enter an invalid parameter, an error message is displayed after you click *Apply*, informing you of the valid options and letting you either cancel the command or return to the dialog box to make the appropriate changes.

## Aggregation

Before describing the features and effects of the *Aggregate* button (see page 86), this section provides an introduction to the concept of arrays and distribution as used in the aggregation feature.

### Introduction to Arrays and Distribution

The *Aggregate* button lets you perform simple aggregations (for example, sum, min, max, and so on), make arrays, and distribute columns. (See Table 3-1)

**Table 3-1** Aggregate Example 1

| State | Age_bin | Total $ Spent |
|---|---|---|
| CA | 0-20 | $50 |
| CA | 21-40 | $454 |
| CA | 41-60 | $693 |
| NY | 0-20 | $35 |
| NY | 21-40 | $541 |
| NY | 41-60 | $628 |

If you make *Total $ Spent* into an array indexed by the binned column *Age_bin*, the resulting table has only two columns:

**Table 3-2** Aggregate Example 2

| State | Total $ Spent [Age_bin] |
|---|---|
| CA | [$50, $454, $693] |
| NY | [$35, $541, $628] |

In this case, making an array reduces the number of columns by one, and also reduces the number of rows by four. Arrays are useful for the Tree Visualizer tool; they are necessary if you want to use sliders in Scatter Visualizer and Map Visualizer displays.

Distributing columns is similar, but different in several important ways. Instead of producing a single new column holding many values, distributing produces one new column for each value of the index. For example, if in the first table was not made an array, but instead distributed by *Age_bin*, the result is:

**Table 3-3** Aggregate Example 3

| State | Total $_0-20 | Total $_21-40 | Total $_41-60 |
|---|---|---|---|
| CA | $50 | $454 | $693 |
| NY | $35 | $541 | $628 |

Thus, distributing increases the number of columns but decreases the number of rows.

If you have more than one binned column (for example, *Age_bin* and *Sex_bin*), you can make a two-dimensional array (indexed by combinations of *Age_bin* and *Sex_bin*). You also can distribute and make an array at the same time.

This table has two binned columns: one for age, one for sex.:

**Table 3-4** Example of Binning

| State | Age_bin | Sex_bin | Total $ Spent |
|---|---|---|---|
| CA | 0-20 | 1 | $20 |
| CA | 0-20 | 2 | $30 |
| CA | 21-40 | 1 | $220 |
| CA | 21-40 | 2 | $234 |
| CA | 41-60 | 1 | $401 |
| CA | 41-60 | 2 | $292 |

If you make Total $ Spent an array indexed by age, and remove *Sex_bin*, the results are:

**Table 3-5** Results When Making Total $ Spent an Array

| State | Total $ Spent [Age_bin] |
|---|---|
| CA | [$50, $454, $693] |

If you do not remove *Sex_bin*, the results are:

**Table 3-6** Results When Specifying *Sex_bin*

| State | Sex_bin | Total $ Spent [Age_bin] |
|---|---|---|
| CA | 1 | [$20, $220, $401] |
| CA | 2 | [$30, $234, $292] |

If you make an array by both *Age_bin* and *Sex_bin*, the results are:

**Table 3-7** Results of Making an Array by *Age_bin* and *Sex_bin*

| State | Total $ Spent [Age_bin] [Sex_bin] |
|---|---|
| CA | [$20, $220, $401, $30, $234, $292] |

Finally, if you distribute by *Sex_bin* and index by *Age_bin*, the results are:

**Table 3-8** Results of Distributing *Sex_bin* and Indexing by *Age_bin*

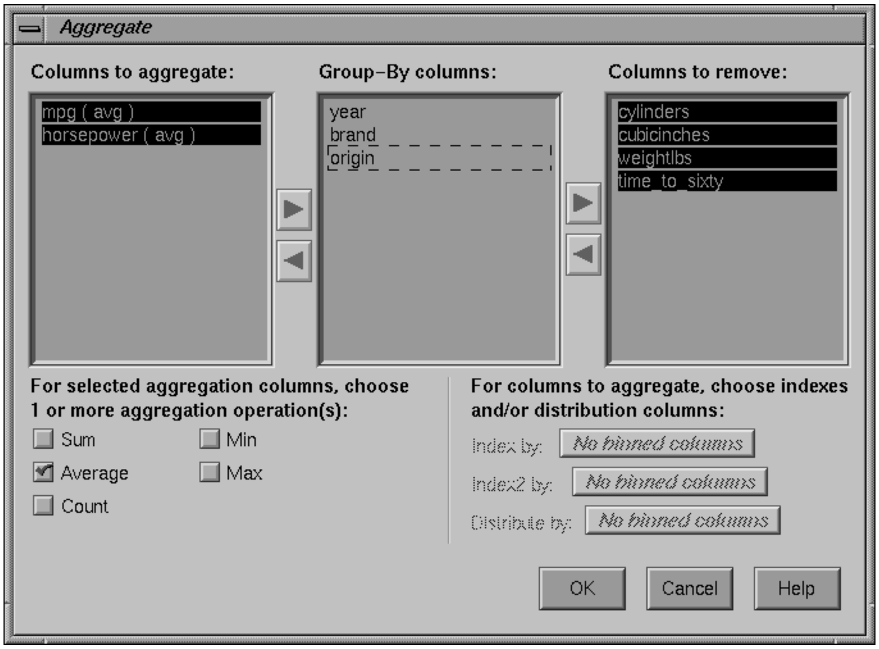
| State | Total $ Spent [Age_bin], Sex = 1 | Total $ Spent [Age_bin], Sex = 2 |
|---|---|---|
| CA | [$20, $220, $401] | [$30, $234, $292] |

The examples above (with the exception of Table 3-5) had exactly one relevant value for each array element, and the distribution merely rearranged existing data values. For the example in Table 3-5, there were two data values for each array element, and these were summed. MineSet provides several aggregation options for datasets containing more than one value to be distributed into a given output array element. The most common option is to add the values (as done in Table 3-5). This is useful when accumulating expenditures into budgets, for example. You also can take the minimum, maximum, and average of the total number of values, as well as count them.

When distributing values for a given dataset, it is possible that there are no values appropriate for a particular bin. In this case, for *min, max, avg,* and *sum* aggregations, the DataMover fills in a value of NULL. For *count* aggregations, the DataMover fills in a value of 0.

### The Aggregate Button

You can use the *Aggregate* button to create simple aggregations, make arrays, or distribute columns. Clicking this button causes the Aggregate dialog box to appear (Figure 3-12). It shows three lists, with the columns in the current table appearing in the middle list. If you want to aggregate, distribute, or turn a column into an array, select the name of the column, and click the left arrow button between the left and center lists. Below are popup menus that let you specify indexes (if the result is to be an array) and a distribution column (if the result is to be distributed). In addition, at the bottom of the dialog box are five toggles that let you specify how different values are to be combined when aggregated: either summed, averaged, the min or max value, or the count. When you are aggregating number-valued columns, you can choose any combination of these options. For other types, only count is permitted. If you choose more than one option, you get more than one result. For example, selecting average and max gives you one result with average values, and another one holding the max values.



Aggregate

Columns to aggregate:
mpg ( avg )
horsepower ( avg )

Group–By columns:
year
brand
origin

Columns to remove:
cylinders
cubicinches
weightlbs
time_to_sixty

For selected aggregation columns, choose 1 or more aggregation operation(s):

□ Sum
☑ Average
□ Count
□ Min
□ Max

For columns to aggregate, choose indexes and/or distribution columns:

Index by: No binned columns
Index2 by: No binned columns
Distribute by: No binned columns

**Figure 3-12** Aggregate Dialog Box

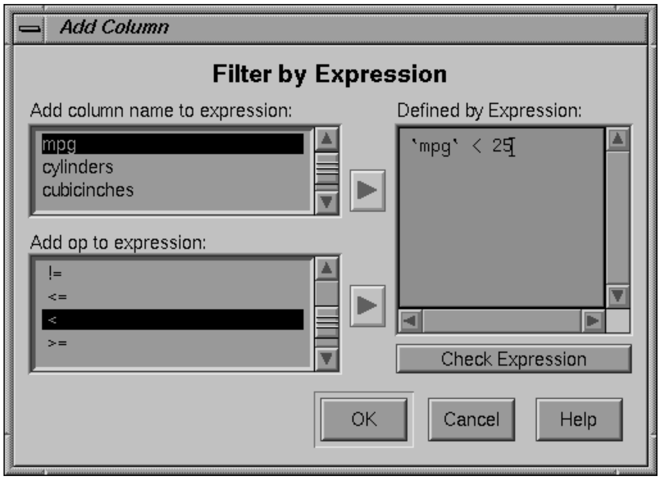
The three lists of column names are given below:

- *Columns to aggregate*.
- *Group-By columns* (the default); this keeps the columns unchanged throughout the operation. For each set of records with the same combination of values in the Group By columns, only one record is output in the resulting table, with values in the aggregated columns summed, averaged, minned, maxed, or counted (depending on the checkboxes at the bottom of the panel).
- *Columns to remove*, as can be seen with the Sex_bin column in Table 3-5

After you have finished with the additional aggregate criteria dialog box, the Current Columns text box in the Table Processing window shows the new column names that result from applying these criteria.

## The Filter Button

This button lets you filter the data via a mathematical expression. The resulting table includes only records for which the expression is true (or, if numerical, non-zero). When you click *Filter*, the Filter dialog (Figure 3-13) appears.



Defined by Expression: `mpg` < 25

**Figure 3-13** Filter Dialog Box

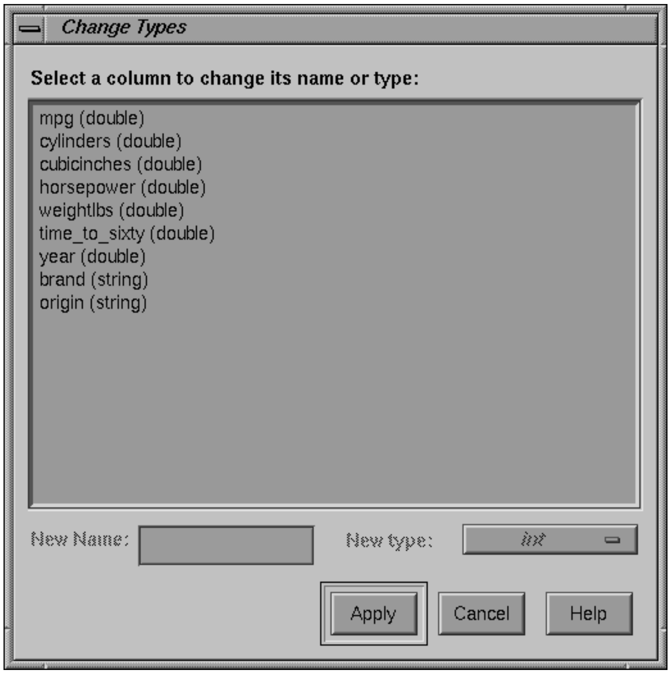
This dialog box lets you select column names and operators on the left to build an expression on the right. For a complete description of the expression definition language, see “The Configuration File” in Appendix B.

## The Change Types Button

This button lets you change the name of a column, as well as its type.

### Changing a Column Type

Some databases store numerical values as strings. Oracle stores all numbers (both integers and real numbers) in a single format, which defaults to the data type *double* in the Tool Manager. You can use the *Change Types* button to ensure that these values are processed correctly. To change the type of one or more columns, click the *Change Types* button. A new dialog box appears (see Figure 3-14). This dialog box contains a window with a list of column headings and their respective types.



Select a column to change its name or type:

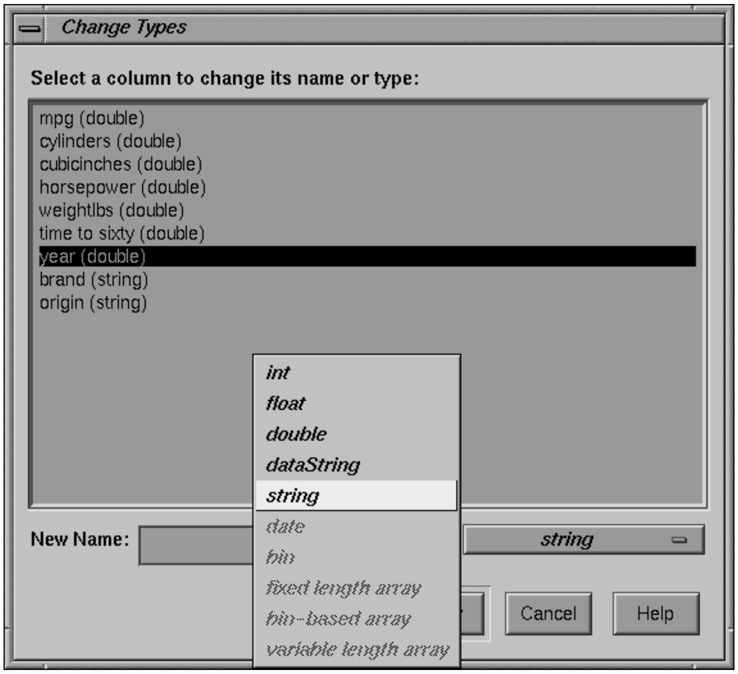
mpg (double)
cylinders (double)
cubicinches (double)
horsepower (double)
weightlbs (double)
time_to_sixty (double)
year (double)
brand (string)
origin (string)

New Name:

New type: *int*

**Figure 3-14** Change Types Dialog Box

First select a column heading in the window. Then click the *New type* button. This produces a popup list of the possible types (invalid types are grayed out), as shown in Figure 3-15.



Change Types

Select a column to change its name or type:

mpg (double)
cylinders (double)
cubicinches (double)
horsepower (double)
weightlbs (double)
time to sixty (double)
year (double)
brand (string)
origin (string)

New Name:

string

**Figure 3-15** Types Popup List

- *int*—represents a 32-bit signed integer.
- *float*—represents a single-precision floating-point number. The decimal point is optional when representing a floating-point number.
- *double*—represents a double-precision floating-point number. The decimal point is optional when representing a floating-point number.
- *dataString*—represents a string that is unlikely to appear multiple times. If it appears multiple times, several copies are made. A *dataString* can be used to store an address. Addresses are unlikely to be compared, and each record can have a different address.

- *string*—represents a string of characters that can appear multiple times in the data file. Unlike a *dataString*, only a single copy of a given string is stored in memory, no matter how many times it appears in the data. This saves memory for strings appearing many times.

  Comparing *strings* is also much quicker than comparing *dataString*s. However, reading in strings can be slower than reading in *dataString*s because it is necessary to look for duplications. An example of *string* use would be for a division name that appears once for each department in the division. If you are unsure whether to use a *string* or a *dataString*, use a *string*.
- *date*—represents the date type from the database.
- *bin*—represents a column created by a binning operation.
- *fixed-length array*—an array of values of fixed size, not created by the Tool Manager.
- *bin-base array*—an array of values as can be created by the Tool Manager.
- *variable-based array*—an array of values of variable size, not created by the Tool Manager.

After selecting a new type, click *Apply* to have the change take effect.

If you try to convert an inappropriate field (such as a name) to a number, the resulting values are all zeroes.

**Note:** When the data source is an existing file, there are fewer possibilities available for changing any given column.

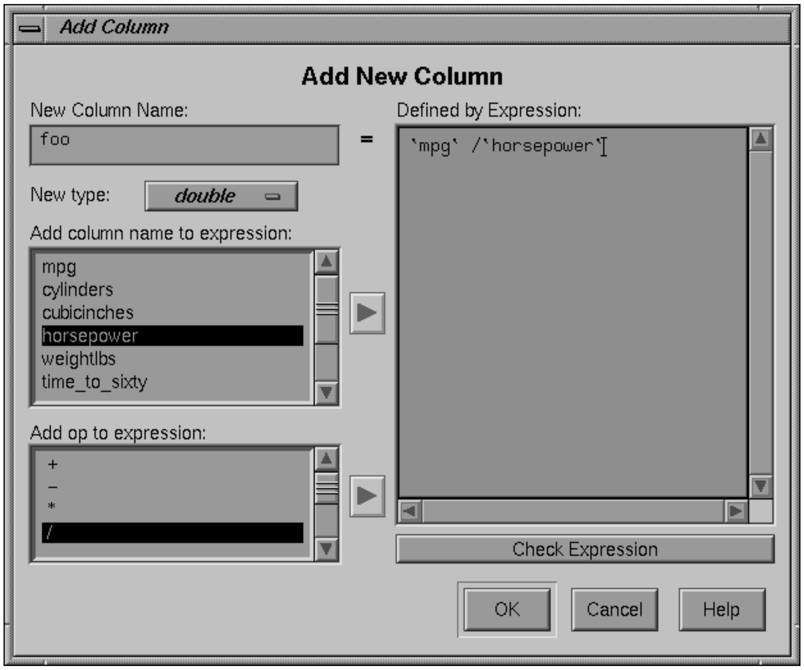
#### Changing a Column Name

Select the original column, type a new name in the text field, and click *Apply*. Then click *Close*.

To exit this dialog box, click *Close*.

## The Add Column Button

You can use the *Add Column* button to create a new column whose values are computed based on a mathematical expression. For example, you could add a new column whose values are the ratio of values from two existing columns. Click *Add Column* to get a dialog box that lets you specify the new column name and expression (Figure 3-16).



Add New Column

New Column Name: foo

New type: double

Defined by Expression: `mpg` /`horsepower`

**Figure 3-16** The Add Column Dialog Box

In the upper left of this dialog box is a field for entering the new column's name. Below this is a popup menu that lets you specify the column type (integer, string, floating point, and so on).

The right-hand side of the dialog contains a large text entry area where you can type in a definition of the expression (for a complete description of the expression definition language, see “The Configuration File” in Appendix B). As a shortcut to typing column names and operators, scrolled lists in the lower left of the dialog display all columns in the current table and all possible operators. To insert a column name or operator into the expression, either double-click it in its scrolled list, or select it and click the arrow button to the right of the scrolled list.

To check the expression you have created, click the *Check Expression* button. If there is an error, a dialog box appears, indicating what the error is and where it occurred. When you click *OK*, the expression is automatically checked, and the dialog box is not removed unless the expression is correct.

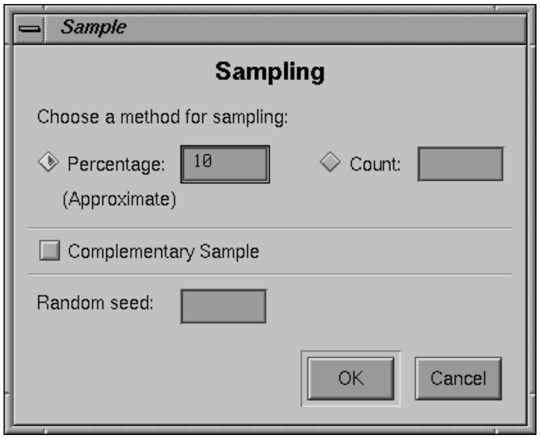
The Add Column dialog box checks for type compatibility: if you have assigned a numerical expression to a string column (or vice versa), a warning message appears, and the type of the new column is automatically changed to be correct.

## The Apply Model Button

The *Apply Model* button lets you use a previously created model to label new records in the current table, to estimate probabilities for a label value, to test the performance of the model on the current table, or to backfit the current table onto an existing model. See Chapter 10, “MineSet Inducers and Classifiers,” for details.

## The Sample Button

This button lets you select a random subset of the data. This is useful for data sets that are too large to work with efficiently. When you click *Sample*, the Sampling dialog box (Figure 3-17) appears.



Sample

Sampling

Choose a method for sampling:

● Percentage: 10 (Approximate)

○ Count:

□ Complementary Sample

Random seed:

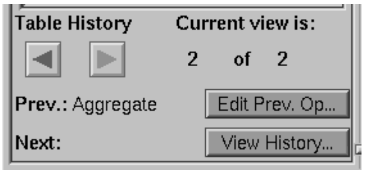
**Figure 3-17** Sampling Dialog Box

You can sample two ways: as a percentage of the current table, or by setting the maximum number of records to put in the sample. Percentage sampling is approximate, you can get slightly more or slightly fewer records than the exact percentage would indicate. The random sample is based on a numeric seed that can be specified in the sampling dialog. If no seed is specified, the number 1 is used as the seed. If you want a different random sample, specify a different random seed.

When you click the *Complementary Sample* toggle, you get all records except those that fall in the random sample. That is, if you get a 10% sample with the *Complementary Sample* not clicked, when you click it, you get the remaining 90% of the data.

## The Table History Buttons

Table processing is a series of operations performed by using the buttons described above. To allow you to see this series of steps, and go back if you made a mistake, there are two *Table History* buttons at the bottom of the Table Processing panel (Figure 3-18). When you click the left arrow button, the columns window shows the table as it appeared at an earlier step. Clicking the right arrow button returns the table to its current state.


Current view is: 2 of 2

Prev.: Aggregate

Next:

**Figure 3-18** Table History Buttons

## The "Current view is" Field

To the right of the history buttons is the information field *Current view is*, which counts the changes you've made and indicates which step you are viewing. The two integers in this field indicate which table view you're looking at, out of the total number of table views that exist. For example, if you've made two changes, you can view the original table (1 of 3), the table after the first change (2 of 3), or the table after the second change (3 of 3).

## The Prev and Next Buttons

As you go back and forth using the *Table History* buttons to view earlier versions of the table, the *Prev:* and *Next:* fields (under the arrow buttons) help you keep track of where you are in the history of the table. For any table you view, the *Prev:* field tells you what the previous change was, and the *Next:* field tells you the next change.

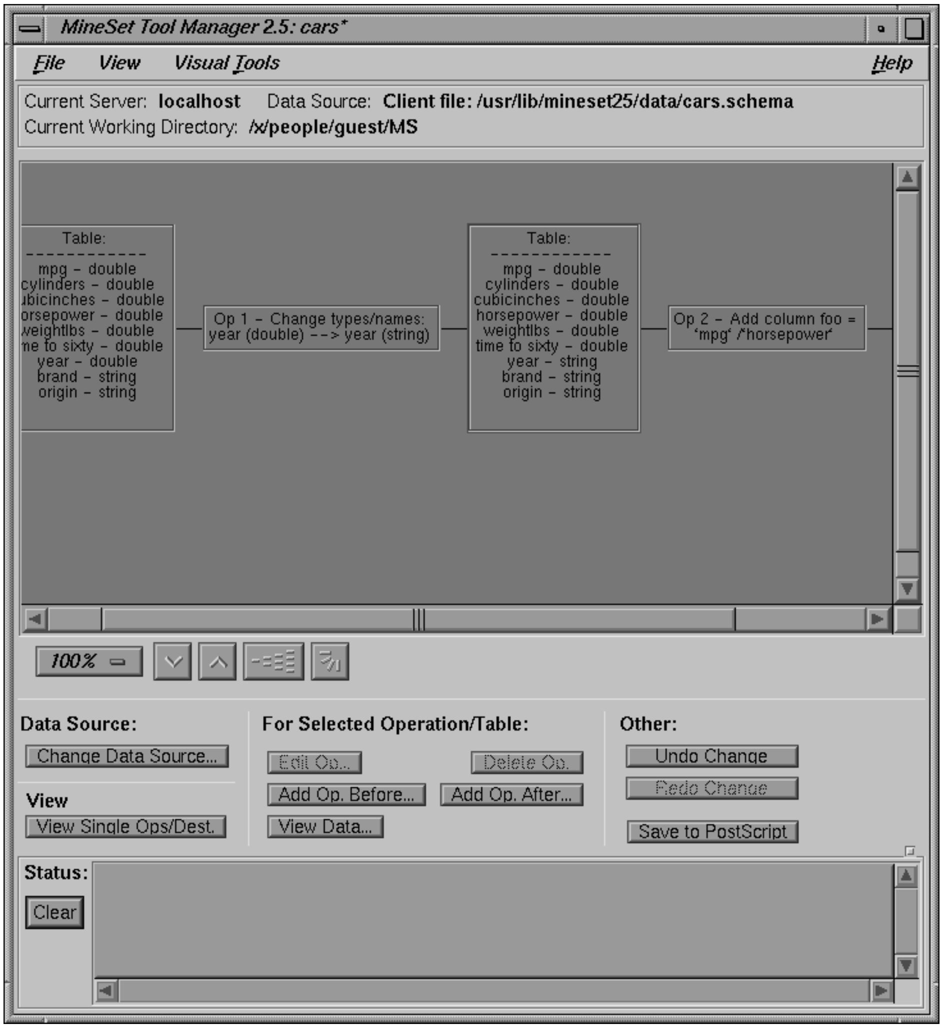
### The Edit Prev. Op Button

The *Edit Prev. Op.* button allows you to edit the operation shown in the *Prev.* field. (This button is not active when *Current view is: 1 of some number*, because that is the original table, with no previous changes.) When you click the *Edit Prev. Op.* button, the dialog box for the previous operation comes up, and you can make changes to that operation. For example, if the previous operation was binning columns, when you click *Edit Prev. Op.*, the *Bin Columns* dialog box appears.

Note that by changing a previous operation, you could affect operations you set up subsequent to the current one. For example, if you delete a column that you used in a subsequent binning operation, that binning operation becomes invalid. The *Edit History* button can help you avoid such problems.

### The View History Button

When you click the *View History* button, the panels showing the current column and data destination are replaced by a panel showing you the complete history of the *Data Transformation* table (Figure 3-19). Each version of the table appears as a box containing a list of the columns, linked by a smaller box (indicating the operation performed on the table) to the next version of it.



MineSet Tool Manager 2.5: cars*

Current Server: **localhost** Data Source: **Client file: /usr/lib/mineset25/data/cars.schema**
Current Working Directory: **/x/people/guest/MS**

```
Table:
------------
mpg - double
cylinders - double
ubicinches - double
orsepower - double
weightlbs - double
me to sixty - double
year - double
brand - string
origin - string

Op 1 - Change types/names:
year (double) --> year (string)

Table:
------------
mpg - double
cylinders - double
cubicinches - double
horsepower - double
weightlbs - double
time to sixty - double
year - string
brand - string
origin - string

Op 2 - Add column foo =
'mpg' /'horsepower'
```

**Figure 3-19** View History Dialog Box

As with *Edit Prev. Op*, changing one operation usually affects (sometimes invalidates) subsequent operations in the history. You can select a specific operation to edit, add, or view. The View History dialog warns you when changes affect the history, shows you the new history. The row of buttons beneath the diagram window of the View History panel allows you to change the size and orientation of the diagram as detailed below.

### Zoom Buttons

Under the window displaying this flow chart are the zoom buttons that let you view the flow chart closer up or farther away (Figure 3-20). You can choose the zoom by using the button indicating the percentage, or by clicking the arrow buttons to increase or decrease the size. The increments of change are the same whether you use the percentage button or the arrow buttons.

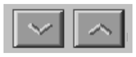


**Figure 3-20** Zoom Buttons

### Overview Button

This button (Figure 3-21) creates, in a separate window, an overview of the entire history chart that is synchronized with the Edit History dialog. The overview window shows you which part of the history is currently visible, and lets you pan to other parts of the history.

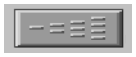


**Figure 3-21** Overview Button

### Vertical/Horizontal View Button

Next to the zoom buttons is a toggle button that lets you view the flow chart vertically or horizontally (Figure 3-22). Clicking the button switches you back and forth between the two points of view.

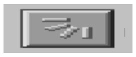


**Figure 3-22** Vertical/Horizontal View Button

### Data Source

Under the Data Source heading is the *Change Data Source...* button, which lets you change the table on which the history operates. When you hold the button down, a menu appears that lets you choose

- ...to DBMS table
- ...to DBMS query
- ...to Data File

Selecting one of these items causes a dialog box to appear that lets you select the new data source.

**Note:** As with editing the history, changing the data source can invalidate history operations.

### View

Under the indicator *View* is a *View Single Ops/Dest* button. When this button is pressed, the panel showing the history is hidden, and the panels showing current columns and data destinations return to view. The function of this button is the same as choosing the *Single Ops and Destination* option from the View pulldown menu at the top of the window.

### For Selected Operation/Table

Under the indicator *For Selected Operation* are three rows of buttons that become active if you click one of the operations or tables in the flow chart. Once you select an operation, you can alter it.

- The *Edit Op* button brings up the dialog box for the selected operation, so you can make changes to it.
- The *Delete Op* button removes the operation from the table history, and the elements that follow in the flow chart move over when it disappears.
- The *Add New Op. Before* and *Add New Op. After* buttons let you insert a new operation into the table history.
- The *View Data* button shows the data for any selected table in the history. When you click this button, a menu is displayed enabling you to select the entire dataset, or a random sample of 10, 100, or 1,000 records.

### Other

Under the indicator *Other* there are three buttons that affect the total history file:

- *Undo Change*—undoes the most recent change to the history (except changes to the data source)
- *Redo Change*—redoes any change you have undone.
- *Save to PostScript*—save a picture of the history flow chart to a file in PostScript format.

## Investigating the Data

The *Data Destination* panel (Figure 3-23) lets you direct your processed data to one of the MineSet visualization or mining tools, or to a data file.

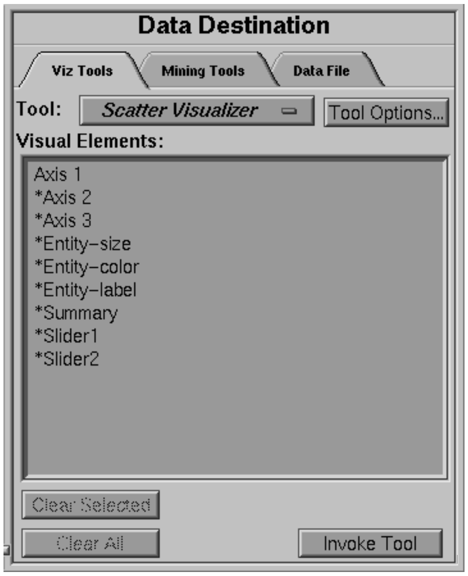
There are three tabs at the top of this panel:

- *Viz Tools*
- *Mining Tools*
- *Data Files*

These are the three possible destinations for your data. They are discussed in greater detail in later chapters dealing with the Data Destination tools.

### Using Visualization Tools

If you choose the *Viz Tool* tab, the visualization tool panel appears under Data Destination (Figure 3-23).



Tool: Scatter Visualizer

Visual Elements:

Axis 1
*Axis 2
*Axis 3
*Entity–size
*Entity–color
*Entity–label
*Summary
*Slider1
*Slider2

**Figure 3-23** Data Destination Panel

*Viz Tool* is a popup menu that lets you choose among *Map Visualizer*, *Scatter Visualizer*, *Splat Visualizer*, *Tree Visualizer*, *Statistics Visualizer* and *Record Viewer*, to determine the type of visual representation you want for your data.

The first five tools are described in their respective chapters.

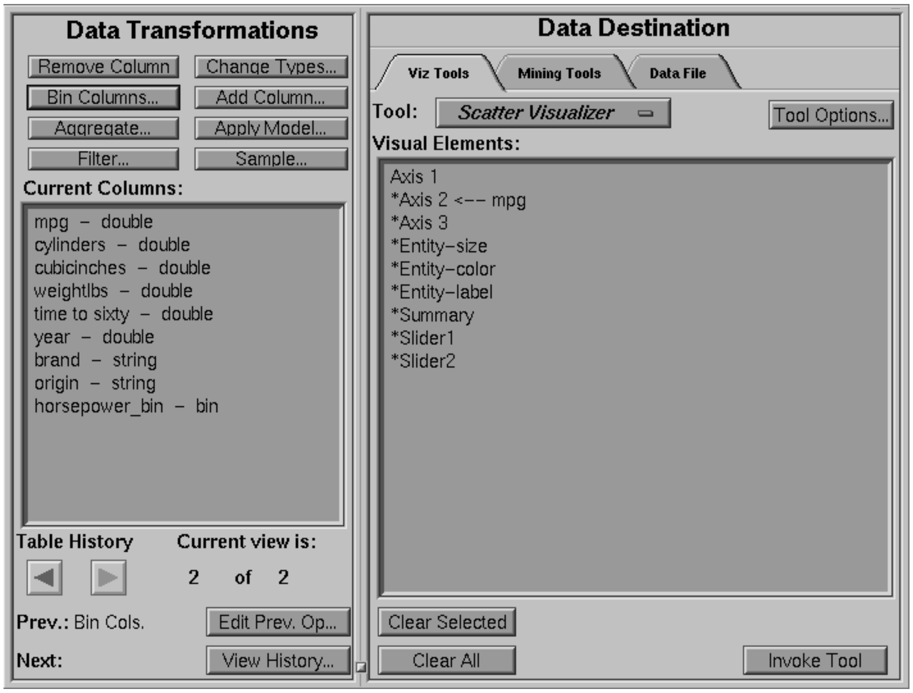
The Record Viewer lets you view the data in the current table in a row/column spreadsheet-like tool. To use the Record Viewer select it from the tool menu, and click *Invoke Tool*.

- *Tool Options*—lets you further specify options you want to set in the specified tool's configuration file.
- *Clear Selected*—lets you undo the mapping to a selected Visual Element.
- *Clear All*—clears all mappings.
- *Invoke Tool*—lets you start the tool you specified (via the top button) using the configuration file named in the *Saved as* text field.

Each tool's requirements are listed individually in the *Visual Elements* pane. This pane lets you map a table column to a requirement. To do this,

1. Select a column by clicking its name in the Current Columns pane.
2. Select the requirement to which you want to map the column by clicking on that requirement in the *Visual Elements* pane.

The *Viz Tool* panel now shows the Visual Element and the column to which it has been mapped (see Figure 3-24).



Current Columns:

mpg – double
cylinders – double
cubicinches – double
weightlbs – double
time to sixty – double
year – double
brand – string
origin – string
horsepower_bin – bin

Current view is: 2 of 2

Prev.: Bin Cols.

Next:

Tool: Scatter Visualizer

Visual Elements:

Axis 1
*Axis 2 <-- mpg
*Axis 3
*Entity–size
*Entity–color
*Entity–label
*Summary
*Slider1
*Slider2

**Figure 3-24** Columns Mapped to Requirements

You can clear the mapping at any time by selecting the requirement that has the mapping you want to change, then clicking the *Clear Selected* button. You can clear all mappings using the *Clear All* button.

If you want to specify other details to fine-tune your mappings or to change the settings so that the data representations more clearly reflect your intentions, click the *Tool Options* button. A dialog box specific to each MineSet tool appears, where you can manually specify the options to use.

**Note:** For details on a specific tool's options, see that tool's chapter.

## Using Mining Tools

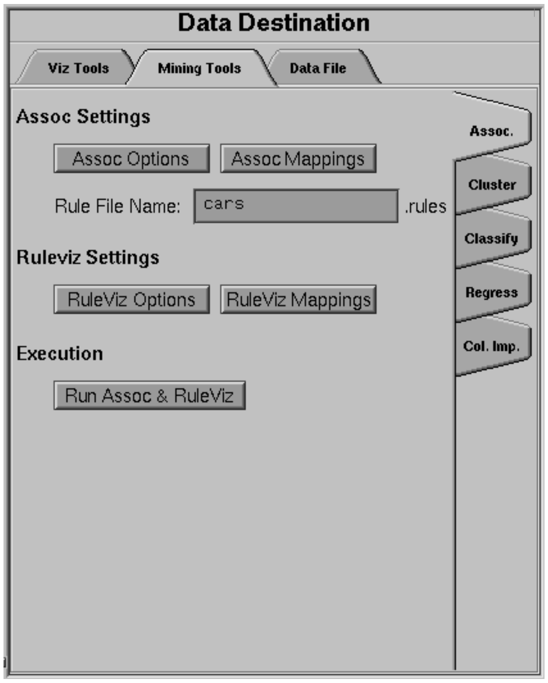
The MineSet Classifiers are described in Chapter 10, "MineSet Inducers and Classifiers," Chapter 11, "Inducing and Visualizing the Decision Tree Classifier," Chapter 12, "Inducing and Visualizing the Option Tree Classifier," Chapter 13, "Inducing and Visualizing the Evidence Classifier," Chapter 14, "Inducing and Visualizing the Decision Table," Chapter 15, "Inducing and Visualizing the Regression Tree." Clustering is described in Chapter 16, and Column Importance is described in Chapter 17.

### Creating Associations for the Rule Visualizer

If you click the Mining Tools tab, then the *Associations* tab, the panel lets you take the data file you created in Data Transformations and proceed to the *Rule Visualizer*. Each step of the process is shown in the subpanels:

- *Assoc Settings*—creates rule generation options and mappings from the columns in your table to elements of association rules
- *Ruleviz Settings*—provides options to tailor the representation of the association rules in the Ruleviz tool
- *Execution*—a button to invoke the process of finding association rules and visualizing them

If you don't want to go through this process manually, click the *Execution* button, and the computer will perform the process using defaults.

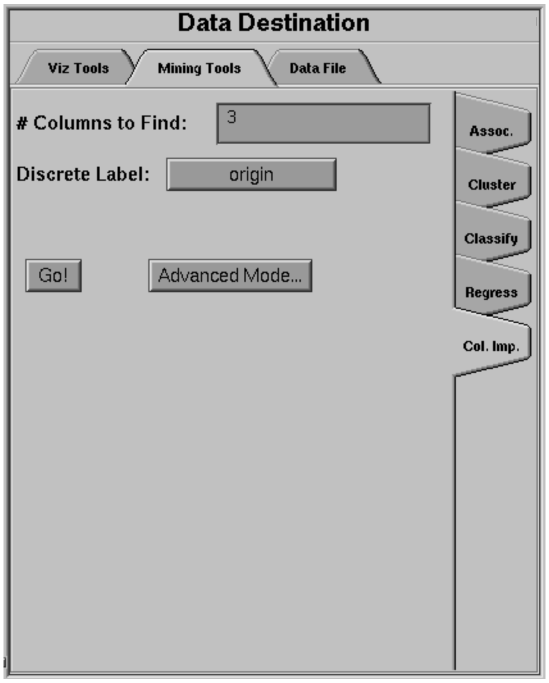


Rule File Name: cars .rules

**Figure 3-25** The Associations Tab

### Finding Important Columns

The *Column Importance* (Figure 3-26) allows you to determine how important various columns are in discriminating the different values of the label column you choose. You might, for example, want to find the best three columns for discriminating the label *good credit risk* so you can choose them for the Scatter Visualizer. When you select the label and click *Go!*, a popup window appears with the three columns that are the best three discriminators. A measure called “purity” (a number from 0 to 100) informs you how well the columns discriminate the different labels. Adding more columns can only increase the purity.



# Columns to Find: 3

Discrete Label: origin

**Figure 3-26** The Column Importance Tab

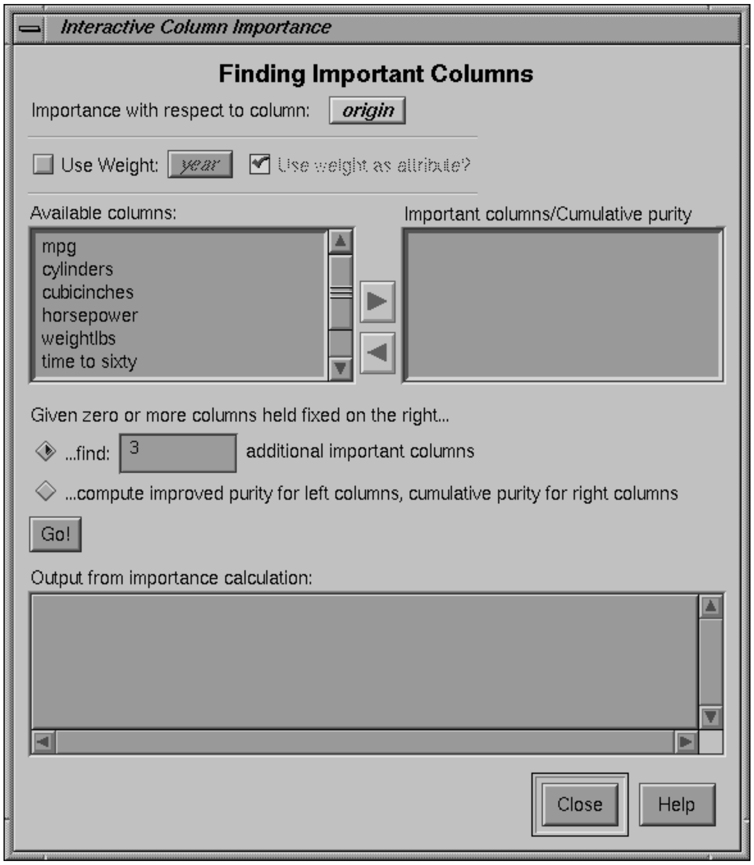
There are two modes of column importance:

- Simple Mode

  To invoke the simple mode, choose a discrete label from the popup menu, and specify the number of columns you want to see.

- Advanced Mode

  Advanced mode lets you control the choice of columns. To enter advanced mode, click *Advanced Mode* in the Column Importance panel. A dialog box appears, as shown in Figure 3-27. The dialog box contains two lists of column names: the left list contains available attributes, and the right list contains attributes chosen as important (by either the user or the column importance algorithm).



Interactive Column Importance

Finding Important Columns

Importance with respect to column: origin

□ Use Weight: year ☑ Use weight as attribute?

Available columns:

mpg
cylinders
cubicinches
horsepower
weightlbs
time to sixty

Important columns/Cumulative purity

Given zero or more columns held fixed on the right...

● ...find: 3 additional important columns

○ ...compute improved purity for left columns, cumulative purity for right columns

Output from importance calculation:

**Figure 3-27** Advanced Mode of Column Importance

Advanced mode can work two different ways: finding several new important attributes, or ranking available attributes.

- Finding Several Important Attributes

  To enter this sub-mode, click the first of the two radio buttons at the bottom of the dialog (*...find [number] additional important columns*). If you click *Go!* with no further changes, the effect is the same as if you were in Simple Mode, finding the specified number of important columns and automatically moving them to the right column. Near each column, the cumulative purity is given (that is, the purity of all the columns up to and including the one on the line). More attributes can only increase the purity.

  Alternatively, by moving columns names from the left list to the right list, you can pre-specify columns that you want included and let the system add more. For example, to select the age column and let the system find three more columns, click the age column name, then click the right arrow.

  Clicking *Go!* lets you see the cumulative purity of each column, together with the previous ones in the list. A purity of 100 means that using the given columns, you can perfectly discriminate the different label values.

- Ranking Available Attributes

  Advanced Mode also lets you compute the change in purity that each column would add to all those that were already selected. For example, you might choose *age*, and then ask the system to compute the incremental improvement in purity that each column would yield.

  To enter this sub-mode, click the second of the two radio buttons at the bottom of the dialog (*...compute improved purity for left columns, cumulative purity for right columns.*). This sub-mode permits fine control over the process. If two columns are ranked very closely, you might prefer one over the other (for example, cheaper to gather, more reliable, easier to understand).

### Column Importance Notes

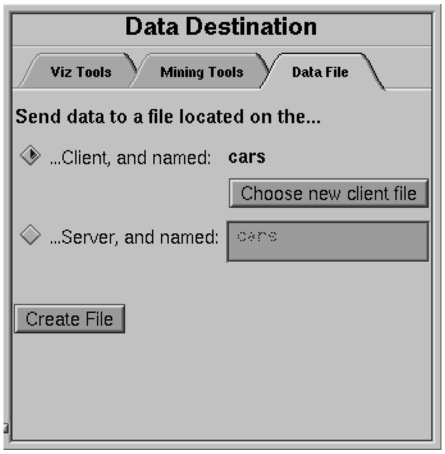
Note that with other columns, the importance of features varies from their ranking alone. For example, while *net-income* might be a good column individually, it might not be as important together with *salary* because they are likely to be highly correlated. The best set of three columns is not necessarily composed of the columns that rank highest individually. If two columns give the income in dollars and in another currency, they are ranked equally alone; however, once one of them is chosen, the other adds no discriminatory power to the set of best features.

Column selection is useful for finding the best three axes for the Scatter Visualizer, as well as for finding a good discriminatory hierarchy for the Tree Visualizer.

All floating point values (double or float) are pre-discretized using the automatic discretization. If a column has no value given to it in the left list, the algorithm did not consider it, because it either had a single value (for example, when it is discretized into one interval), or the number of records that it would separate is not statistically significant.

## Using Data Files

The Tool Manager lets you save the manipulated table for future use in a data file on the client or server. If you click the *Data Files* tab, the panel shown in Figure 3-28 appears.



Send data to a file located on the...

● ...Client, and named: cars

○ ...Server, and named: cars

**Figure 3-28** The Data Files Panel

The two toggle buttons in this panel let you specify whether the file is to be saved on the server or your client machine. The selected name for the client file appears next to the Client checkbox. If you select *Client*, the *Choose new client file* button brings up a dialog for you to choose the name for the client file. If you select *Server*, you can type the server filename directly into the adjacent text field.

**Note:** Pathnames are not permitted for server files; all server files are stored in the DataMover cache directory.

## Session Files

The Tool Manager can save a description of your work to a "session file" for future use. A session file contains a description of the data source you selected, all the transformations on the data, and the mining or visualization of the data. Each session file can hold descriptions of only one data source and one data destination; thus, if you change the destination visual tool or source data table, the session file loses its links to any previous data source or destination.

Session files can be saved at any time through the entries in the File menu, described below. The name of the current session appears in the window's title bar. The Tool Manager also keeps a parallel session file, called *.latest.mineset*, in your home directory. It always has a record of your most recent actions in the Tool Manager. Whenever you start the Tool Manager without a session file, it reads the contents of the *.latest.mineset* file to return you to the state when you last ran MineSet.

Session files also can be used for running the Tool Manager in batch mode, by issuing this command at the UNIX shell prompt:

```
mineset_batch [-s serverPassword -d databasePassword] sessionFile
```

The **-s** and **-d** options let you specify the password for logging into the server and database respectively. If you do not specify these options, *mineset_batch* will ask you to type in the passwords, thus these options are useful when running *mineset_batch* from a shell script. To specify that there is no password for either the server or database, use **-s** or **-d** followed by two double quotes, that is,

```
mineset_batch -s "" -d "" foo.mineset
```

If you specify one of the two passwords, you must specify both.

In batch mode, the Tool Manager does not bring up tools or windows; however, it creates files for tools. For example, if the session file includes the Tree Visualizer as the data destination, running the Tool Manager in batch mode produces files for running the Tree Visualizer, but the Tool Manager does not invoke it.

## Pulldown Menus

At the top of the Tool Manager window (see Figure 3-1 on page 67) are four pulldown menus:

- File
- View
- Visual Tools
- Help

The following section describes each of these menus.

### The File Menu

The File menu lets you choose what to do with your current session, which is one complete session with a tool. This includes choosing the server, data source and table, all the table manipulations, the mapping or classifying of the data, as well as opening or saving a tool history, changing the working directory, and setting preferences.

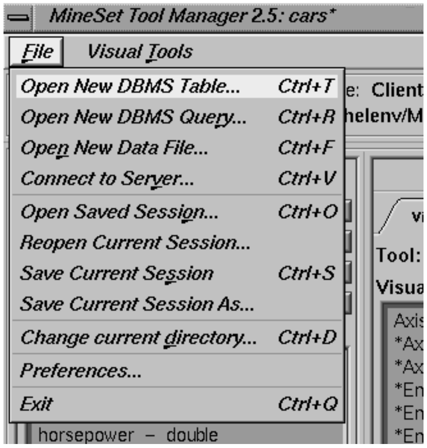

MineSet Tool Manager 2.5: cars*
File
Visual Tools
Open New DBMS Table... Ctrl+T
Open New DBMS Query... Ctrl+R
Open New Data File... Ctrl+F
Connect to Server... Ctrl+V
Open Saved Session... Ctrl+O
Reopen Current Session...
Save Current Session Ctrl+S
Save Current Session As...
Change current directory... Ctrl+D
Preferences...
Exit Ctrl+Q
e: Client
helenv/M
Tool:
Visua
Axis
*Ax
*Ax
*En
*En
*En
horsepower – double

**Figure 3-29** File Menu

The File menu provides five sets of functions:

- The first set is for selecting a data source.
  - *Open New DBMS Table*—lets you select a single table from a DBMS.
  - *Open New DBMS Query*—lets you make an SQL query against the DBMS.
  - *Open New Data File*—lets you select a table from a data file on disk.
  - *Connect To Server*—lets you open a connection to a MineSet server.
- The second set is for opening or saving *.mineset* files.
  - *Open Saved Session...*—lets you open a *.mineset* file.
  - *Reopen Current Session* —lets you reopen the current session file from the disk, in case you do not want to save the current changes.
  - *Save Current Session*—lets you save a currently open *.mineset* file.
  - *Save Current Session As...*—lets you name (or rename) and save a currently open history as a *.mineset* file.
- The third set is for changing the current directory.
  - Change Current Directory—lets you specify the directory in which the Tool Manager creates all data and visualization files.
- The fourth set is for setting preferences. Here you can specify whether to
  - use ASCII or binary files
  - include an entry for NULL values when creating arrays
  - automatically load the most recent session when starting up the Tool Manager
  - run MIndUtil in single- or multi-threaded mode; a slider allows you to select how many threads to use.
- The last option, Exit, lets you end the current session and exit the Tool Manager.

## The View Menu

The View Menu lets you select whether to see the history panel or the current columns and data destination panels.

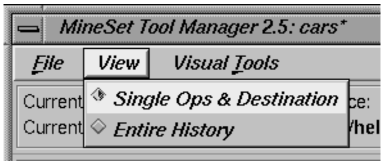


**Figure 3-30** View Menu

- *Single Ops and Destination*—shows the current columns and data destination panels. This menu option performs the same function as the *View Single Ops/Dest* button on the history panel.
- *Entire History*—shows the history panel. This menu option performs the same function as the *View History* button on the Data Transformations panel.

## The Visual Tools Menu

The Visual Tool menu lets you invoke any of the following visual tools directly:

- Cluster
- Decision Table
- Evidence Visualizer
- Map Visualizer
- Rule Visualizer
- Scatter Visualizer
- Splat Visualizer
- Statistics Visualizer
- Record Viewer
- Tree Visualizer

If you have created a file that runs within one of these tools, and you want to go back to it, click the tool. From within the tool, use File > Open to open the data file. These viewers are described in their respective chapters, except for Record Viewer, which is described later in this chapter, in "The Record Viewer" on page 113.

### The Help Menu

The Help menu provides information about the elements of the Tool Manager and how they work:

- Click for Help—Gives help information about a particular item if you press *Shift-F1*, then click the item for which you want help.
- Overview—Gives an overview of the online help and how to use it.
- Index—Provides an index of the complete help system. This option is currently disabled.
- Keys & Shortcuts—Provides the keyboard shortcuts for all of the Tree Visualizer's functions that have accelerator keys.
- Product Information—Indicates what version of the Tool Manager you are using.
- *MineSet User's Guide*—Invokes the IRIS Insight viewer with the online version of this manual.

## The Tool Manager Options File

The Tool Manager creates a *.mineset* file in your home directory. This is used to store the preference indicating whether to restore the most recent session on startup, as well as the default server name, login, and password. If you log in to the same server often, edit this file and specify a server name and login as follows:

```
default_server_name: mineset
default_server_login: guest
default_server_password:
```

Whenever you try to log in to a server, these names appear as defaults.

**Warning: Putting a password in a file is a great security risk. Do not place a password in the Tool Manager options file unless you want other people to know that password.**

## The Record Viewer

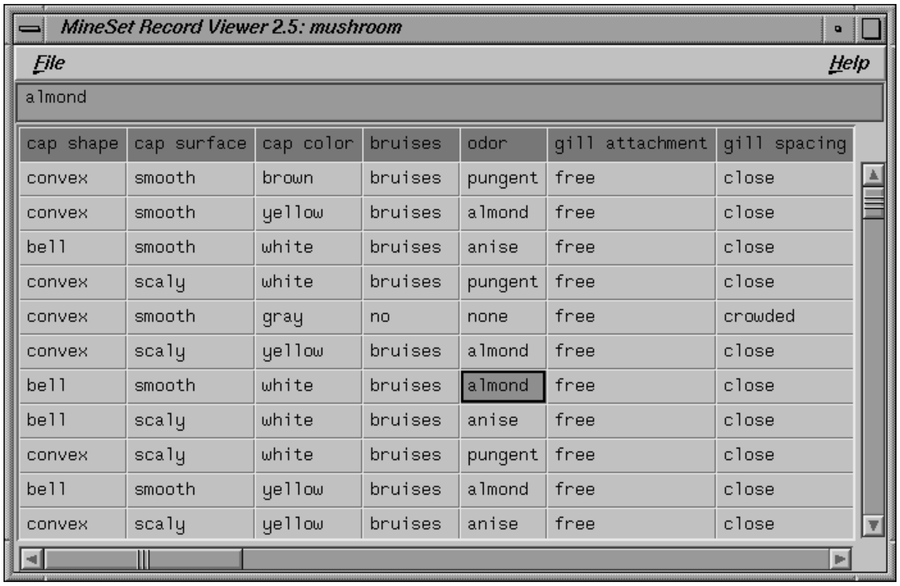
The Record Viewer lets you view MineSet data files in a format similar to spreadsheets. There are five ways to start the Record Viewer.

- Use the Tool Manager to start the Record Viewer. This invokes the Record Viewer on the data currently configured in the Tool Manager.
- Double-click on the Record Viewer icon, which is in the MineSet page of the icon catalog. Since no *.schema* file is specified, you must select one by using File > Open.
- Double-click on any MineSet *.schema* file. This launches the Record Viewer on that *.schema* file.
- Drag a *.schema* file onto the Record Viewer icon.
- Start the Record Viewer from the UNIX shell command line by entering this command at the prompt:

  ```
  recordview [ file.schema ]
  ```

  where `file.schema` is optional and specifies the name of the *.schema* file to use. If you do not specify a *.schema* file, you must use File | Open to specify one.

The Record Viewer shows the data specified by the *.schema* file in spreadsheet format (see Figure 3-31).



almond

| cap shape | cap surface | cap color | bruises | odor | gill attachment | gill spacing |
|---|---|---|---|---|---|---|
| convex | smooth | brown | bruises | pungent | free | close |
| convex | smooth | yellow | bruises | almond | free | close |
| bell | smooth | white | bruises | anise | free | close |
| convex | scaly | white | bruises | pungent | free | close |
| convex | smooth | gray | no | none | free | crowded |
| convex | scaly | yellow | bruises | almond | free | close |
| bell | smooth | white | bruises | almond | free | close |
| bell | scaly | white | bruises | anise | free | close |
| convex | scaly | white | bruises | pungent | free | close |
| bell | smooth | yellow | bruises | almond | free | close |
| convex | scaly | yellow | bruises | anise | free | close |

**Figure 3-31** Sample Record Viewer Screen

If a column is not wide enough to see a specific value, click on it to display that value at the top of the Record Viewer. You also can change the width of columns by dragging the separators between the columns.

To read a new *.schema* file into the Record Viewer, select File > Open. To close the Record Viewer, select File > Exit.

Note that some of the visual tools also bring up record viewers to display the current selections. These record viewers are built into the visual tools; while their behavior is the same as the Record Viewer discussed above, they do not allow opening other *.schema* files.

## Color Options for the MineSet Visualizers

Many of the tool option dialogs have options for choosing colors. MineSet has a color list chooser that uses color swatches. This section describes how to choose, apply, and change color options for the MineSet Visualizers.

### Choosing Colors

If only one color is to be chosen (for example a grid color), a single color swatch appears (Figure 3-32).

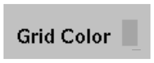
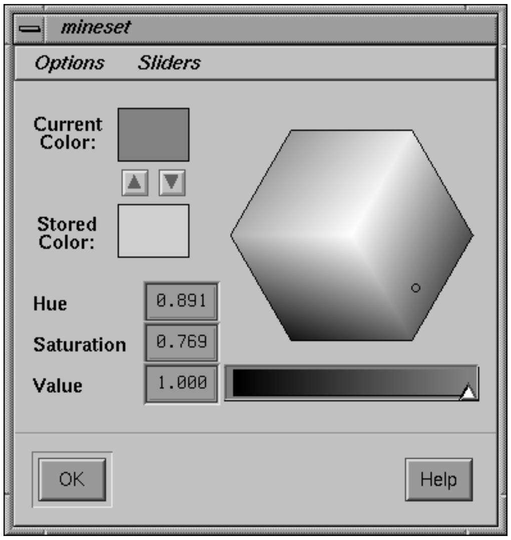


**Figure 3-32** Configuration Option With a Single Color Swatch

Clicking the swatch brings up a Color Browser that lets you change the color of that swatch (Figure 3-33). The Color Browser is described in more detail in the "Using the Color Browser" section, shown in Figure 3-33.



Hue 0.891
Saturation 0.769
Value 1.000

**Figure 3-33** Color Browser

If a list of color swatches is to be chosen, the list of swatches appears (these can be empty initially), as shown in Figure 3-34.

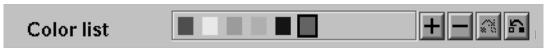


**Figure 3-34** Multiple Colors Swatches

To edit the color, click a swatch with the left mouse button. This also selects the swatch for making changes to the colors with the buttons. If you click on the swatch with the middle mouse button, the swatch is selected, but the color chooser does not appear.

Next to the list of swatches are four buttons. First is the *Add* button, labeled with a plus sign (+*)*, which adds a new color at the end of the list. A swatch is added, and the color chooser appears, where you can select the color of that swatch. The *Add* button is disabled if the maximum number of colors is already in the list.

Next to the *Add* button is a *Delete* button, labeled with a minus sign (-*)*. This button deletes the selected color. It is disabled if no swatch is selected, or if the list already has the minimum number of colors.

Next to the *Delete* button are two buttons to shift the selected color right and left. These buttons are disabled if no swatch is selected, or if the swatch is already at the end of the list.

If there are more colors in the list than room to display them, scroll arrows are added at each end of the list (Figure 3-35).

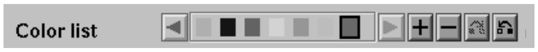


**Figure 3-35** Scroll Arrows on Color Browser

If the hardware runs out of colors, the color swatches are replaced with text labels showing the color in X notation (Figure 3-36).

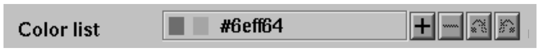


**Figure 3-36** Color Browser Out of Colors

### Using the Color Browser

The Color Browser (Figure 3-33) appears when you click a color swatch or the add button in the Colors panel of the visualizer's Configuration Options panel.

To select a color using the Color Browser:

1. Move your mouse cursor on top of the small circle in the colored hexagon.
2. Press the left mouse button, and move your mouse around the hexagon. The color beneath the small circle appears in the rectangle next to the *Current Color* label. This rectangle acts as your color palette while you choose a color.
3. Release the mouse button when the small circle is on top of a color you want. The selected swatch immediately takes on the chosen color.

   You can edit several colors without dismissing the Color Browser; clicking any color in the options panel lets you edit that color in the already posted Color Browser.
4. Click the *OK* button when you decide on a color. The Color Browser window closes.

*Chapter 4*

# Using the Statistics Visualizer

This chapter discusses the features and capabilities of the Statistics Visualizer. It provides an overview of this data visualization tool, then explains the Statistics Visualizer's functionality when working with the

- main window
- external controls
- pulldown menus

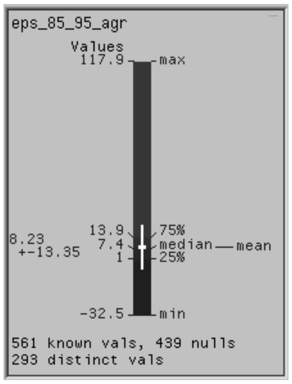
Finally, it lists and describes the sample files provided for this tool.

## Overview of the Statistics Visualizer

The Statistics Visualizer lets you visualize statistics on columns. Statistics Visualizer presents a window that contains one small panel for each column listed in the *Current Columns* pane of Tool Manager. The Statistics Visualizer main window has a default size and shows only a restricted number of column panels. If the number of columns is large, scrollbars appear; alternatively, you can stretch the Statistics Visualizer window horizontally or vertically to view more column panels.

The format of the column panel varies according to the column type, and the number of distinct values that exist for that column. Columns are generally divided into two types: *numeric* and *discrete*, shown as box plots and histograms, respectively.

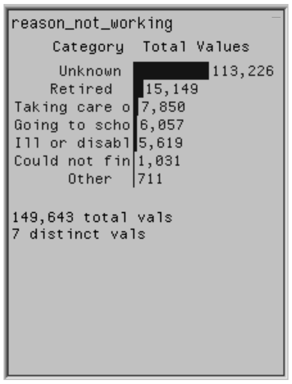
A *numeric* column has integer, float, double or date values. Each box plot panel shows statistics about data from a single column, including the minimum, maximum, mean, median, and two quartiles (25th and 75th percentiles) of these numeric values. These values are shown as lines across a vertical bar in graduated shades of green, and the standard deviation of the population is shown as a +/- value. The quartiles are shown whenever there are fewer than 50,000 distinct values, (see Figure 4-1). If there are more than 50,000 distinct values in the column, the statistics are shown as a gray vertical bar.



```
561 known vals, 439 nulls
293 distinct vals
```

**Figure 4-1** Numeric Column Displayed by Statistics Visualizer

A *discrete* (or *nominal*) column has non-numeric (string, bin, or enum) values shown as histograms, (see Figure 4-2). The discrete column panel shows up to 100 distinct values, as well as a histogram of the number of instances of this distinct value. The default ordering of the discrete rows is by decreasing count, but you can use the View pulldown menu to select an alternative sorting. If there are 100 or fewer distinct categories, then the column panel also contains the count of distinct values.


reason_not_working

| Category | Total Values |
|---|---|
| Unknown | 113,226 |
| Retired | 15,149 |
| Taking care o | 7,850 |
| Going to scho | 6,057 |
| Ill or disabl | 5,619 |
| Could not fin | 1,031 |
| Other | 711 |

```
149,643 total vals
7 distinct vals
```

**Figure 4-2** Discrete Column Displayed by Statistics Visualizer

After creating a visualization of your data, the Statistics Visualizer lets you see truncated textual information in the histograms with a brush highlighter. The brush highlighter activates as you pass the mouse across a field without clicking.

## File Requirements

The Statistics Visualizer requires a data file, consisting of ASCII or binary fields. This file is easily created when running the Tool Manager (see Chapter 3).

## Starting the Statistics Visualizer

There are five ways to start the Statistics Visualizer:

- Use the Tool Manager to configure and start the Statistics Visualizer. See Chapter 3 for details on most of the Tool Manager's functionality, which is common to all MineSet tools.
- Double-click the Statistics Visualizer icon, which is in the MineSet page of the icon catalog. The icon is labeled *statviz*. Since no configuration file is specified, the start-up screen requires you to select one by using File > Open.
- Double-click the Statistics Visualizer icon on your Silicon Graphics desktop. The startup screen requires you to select a data file by choosing File > Open.

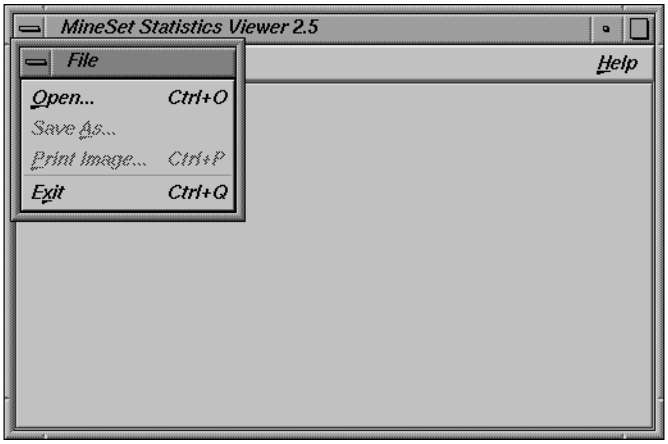


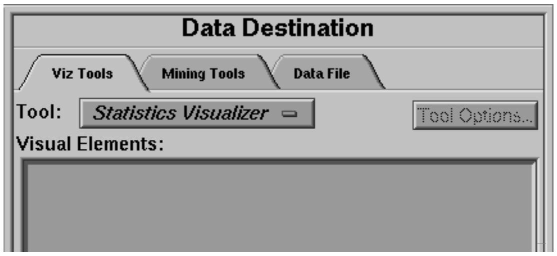
**Figure 4-3** File > Open Menu Selection for Statistics Visualizer

Starting the Statistics Visualizer from the icon activates only the File and Help pulldown menus. For the main window to be fully functional, open a *.statviz* file by selecting File > Open.

- If you know what *.statviz* file you want to use, double-click the icon for that file. This starts the Statistics Visualizer and automatically loads the file you specified. This works only if the filename ends in *.statviz* (which is always the case for data files created for the Statistics Visualizer using the Tool Manager).
- Drag the *.statviz* file icon onto the Statistics Visualizer icon. This starts the Statistics Visualizer and automatically loads the file you specified. This works even if the configuration filename does not end in *.statviz*.

## Starting the Statistics Visualizer

Select the *Viz Tools* tab in the Data Destination panel of the Tool Manager's main screen (Figure 4-4). From the popup list of tools, choose *Statistics Visualizer.*



Tool: Statistics Visualizer

**Figure 4-4** Data Destination Panel With Statistics Visualizer Selected

## Working in the Statistics Visualizer’s Main Window

If you started the Statistics Visualizer from the icon, the main window shows the copyright notice and license agreement for the Statistics Visualizer. Only the File and Help pulldown menus can be used. For the main window to show all menus and controls, open a *.statviz* file. Use File > Open (Figure 4-3) to see a list of configuration files.

## Pulldown Menus

Three pulldown menus let you access additional Statistics Visualizer functions. These are labeled File, View, and Help. If you start the Statistics Visualizer without specifying a configuration file, only the File and the Help menus are available.

### The File Menu

The File pulldown menu for the Statistics Visualizer contains four options.

- *Open* loads and opens a file and displays it in the main window.
- *Save As* saves the current state of the Statistics Visualizer main window into an image file
- *Print Image* captures the image of outputs the current state of the Statistics Visualizer main window and prints it to a printer.
- *Exit* closes all windows and exits the application

## The View Menu

The Statistics Visualizer View pulldown menu (Figure 4-5) contains two options.

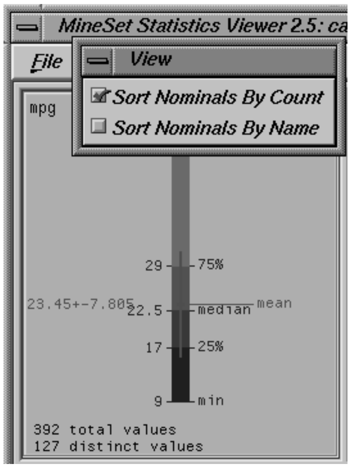


**Figure 4-5** StatViz View Pulldown Menu

- *Sort Nominals By Count* specifies that the nominal (discrete) columns show the histogram of values that is ordered by decreasing per-value counts.
- *Sort Nominals By Name* specifies that those same columns be ordered by the relative alphabetical order of each data value name.

## The Help Menu

The Help menu provides access to five help functions (see Figure 4-6).

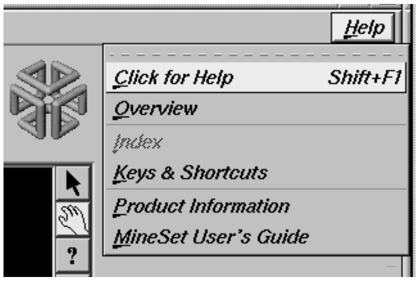


**Figure 4-6** Statistics Visualizer Help Menu

- *Click for Help* turns the cursor into a question mark. Placing this cursor over an object in the Statistics Visualizer's main window and clicking the mouse causes a help screen to appear; this screen contains information about that object. Closing the help window restores the cursor to its arrow form and deselects the help function. The keyboard shortcut for this function is Shift+F1. (Note that it also is possible to place the arrow cursor over an object and press the F1 function key to access a help screen about that object.)
- *Overview* provides a brief summary of the major functions of this tool, including how to open a file and how to interact with the resulting view.
- *Index* provides an index of the complete help system. This option is currently disabled.
- *Keys & Shortcuts* provides the keyboard shortcuts for all of the Statistics Visualizer's functions that have accelerator keys.
- *Product Information* brings up a screen with the version number and copyright notice for the Statistics Visualizer.
- *MineSet User's Guide* invokes the Insight viewer with the online version of this manual.

## Sample Data Files

The provided sample data files demonstrate the Statistics Visualizer's features and capabilities. The following files are in the */usr/lib/MineSet/statviz/examples* directory:

*mushroom.statviz*
*census95.statviz*.

*Chapter 5*

# Using the Tree Visualizer

This chapter discusses the features and capabilities of the Tree Visualizer. It provides an overview of this visualization tool, discusses ways of invoking it, then explains the Tree Visualizer's functionality when working with the following elements.

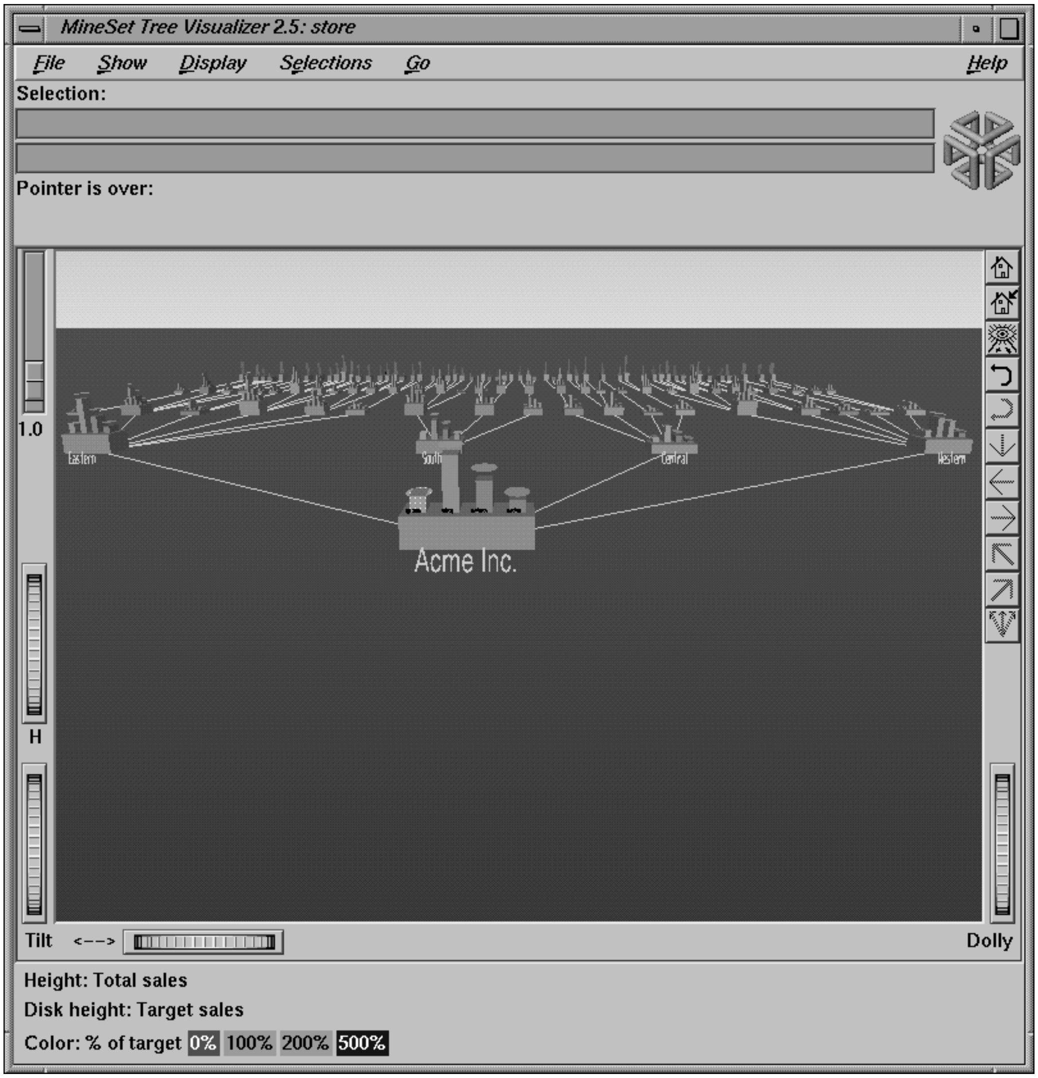
- main window
- external controls
- pulldown menus
- overview window

Finally, this chapter lists and describes the sample files provided for this tool.

## Overview of Tree Visualizer

The Tree Visualizer is a graphical interface that displays data as a three-dimensional "landscape." It presents your data as clustered, hierarchical blocks (nodes) and bars with disks through which you can dynamically navigate, viewing part, or all, of the dataset.

As shown in Figure 5-1, the Tree Visualizer displays quantitative and relational characteristics of your data by showing them as hierarchically connected nodes. Each node contains bars whose height, color and disk correspond to aggregations of data values. The lines connecting nodes show the relationship of one set of data to its subsets.



Height: Total sales

Disk height: Target sales

Color: % of target 0% 100% 200% 500%

**Figure 5-1** Example Display in the Tree Visualizer's Main Window

Values in subgroups can be summed and displayed automatically in the next higher level. The base under the bars can provide information about the aggregate value of all the bars. Bars representing negative values are shown below the top of the base. You can see negative value bars more clearly by disabling the base height (see “The Display Menu” on page 165, or the “Base Height Statements” section in Appendix B, “Creating Data and Configuration Files for the Tree Visualizer”).

## File Requirements

The Tree Visualizer requires the following files:

- A *data* file consisting of rows of tab-separated fields. This file is easily created using the Tool Manager (see Chapter 3). If you are generating this file yourself, see Appendix B, “Creating Data and Configuration Files for the Tree Visualizer” for the required file format.

  Data files are generated by extracting data from a source (such as an Oracle, INFORMIX, or Sybase database) and formatting it specifically for use by the Tree Visualizer. Data files have user-defined extensions (the sample files provided with the Tree Visualizer have a *.data* extension).

- A *configuration* file describing the format of the input data and how these are converted to a hierarchy. This file also is easily created using the Tools Manager (see Chapter 3). You also can use an editor (such as jot, vi, or Emacs) to produce this file (see Appendix B, “Creating Data and Configuration Files for the Tree Visualizer”).

  Configuration files must have a *.treeviz* extension. When starting the Tree Visualizer, or when opening a file, specify the configuration file, not the data file.

## Starting the Tree Visualizer

There are five ways to start the Tree Visualizer:

- Use the Tool Manager to configure and start the Tree Visualizer. (See Chapter 3 first for details on most of the Tool Manager's functionality, which is common to all MineSet tools; see below for details about using the Tool Manager in conjunction with the Tree Visualizer.)
- Double-click the Tree Visualizer icon, which is in the MineSet page of the icon catalog. The icon is labeled *treeviz*. Since no configuration file is specified, the start-up screen requires you to select one by using File | Open.

  Starting the Tree Visualizer without specifying a configuration file causes the main window to show the copyright notice for this tool. Only the File and Help pulldown menus can be used. For the main window to be fully functional, open a configuration file by selecting File | Open (Figure 5-2).

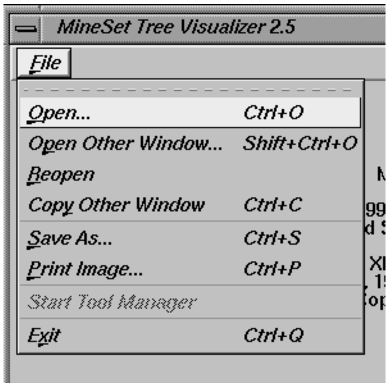


**Figure 5-2** Tree Visualizer's File Pulldown Menu

- If you know what configuration file you want to use, double-click the icon for that file. This starts the Tree Visualizer and automatically loads the file you specified. This only works if the filename ends in *.treeviz* (which is always the case for configuration files created for the Tree Visualizer via the Tool Manager).

- Drag the configuration file icon onto the Tree Visualizer icon. This starts the Tree Visualizer and automatically loads the file you specified. This works even if the filename does not end in *.treeviz*.
- Start the Tree Visualizer from the UNIX shell command line by entering this command at the prompt:

  ```
  treeviz [ configFile ]
  ```

  where *configFile* is optional and specifies the name of the configuration file to use. If you don't specify a configuration file, you must use File > Open to specify one (see Figure 5-2).

### Options for Invoking the Tree Visualizer

There are a two options that affect how this tool is invoked:

- **`-warnexecute`** indicates that if you attempt to execute a command specified in an execute statement, a warning is displayed and you are given the option to execute the command or not. This is intended for an insecure environment, such as files obtained from the Web, and is used automatically when commands are executed via mtr files.

  You can enable this option permanently by adding the line

  ```
  *minesetWarnExecute:TRUE
  ```

  to the user's *.Xdefaults* file, or by setting the environment variable

  ```
  MINESET_WARN_EXECUTE
  ```

- **`-quiet`** eliminates the dialogs that popup to indicate progress. You can enable this option permanently by adding the line

  ```
  *minesetQuiet:TRUE
  ```

  to your *.Xdefaults* file.

## Configuring the Tree Visualizer Using the Tool Manager

This section describes how the Tree Visualizer can be configured using the Tool Manager. Although the Tool Manager greatly simplifies the task of configuring the Tree Visualizer, you can construct a configuration file manually for this tool using an editor (see Appendix B, “Creating Data and Configuration Files for the Tree Visualizer”).

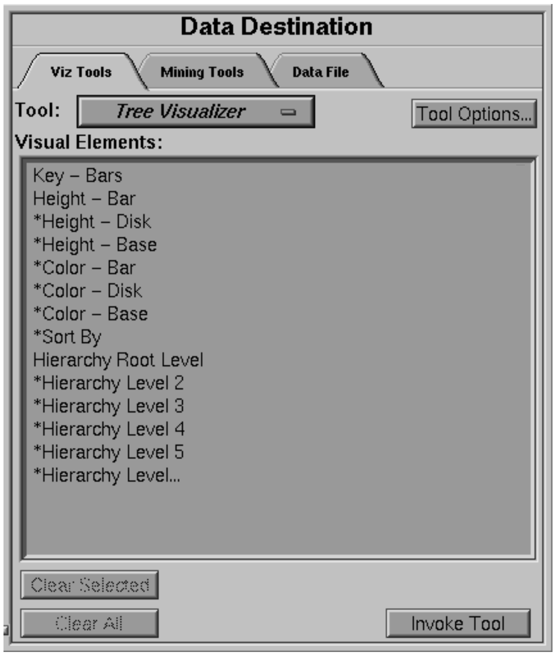
For the Tree Visualizer, the Tool Manager does not support the following:

- Non-aggregated hierarchies where the data is displayed directly without aggregating it.
- Real-time monitoring.
- A number of very rarely used options (skip missing, overview, shrinkage, root label, speed, climb speed, leaf margin, root leaf margin, leaf edge margin, initial position, initial angle, bar label size, base label size, and lod). See Appendix B.
- Variable-length arrays.
- Expressions computed after creating the hierarchy. For example, if you are computing a percentage, the percentage must be computed after the hierarchy aggregation takes place, since it is not possible to aggregate the percentages.

Note that the steps required to connect to a data source are described in Chapter 3.

### Selecting the Tree Visualizer Tool

Select the *Viz Tools* tab in the Data Destination panel of the Tool Manager’s main screen (Figure 5-3). From the popup list of tools, select Tree Visualizer. The mapping requirements for the Tree Visualizer are displayed in the window on the right side of this panel. Items in the Visual Elements: list that are preceded by an asterisk are optional.



Data Destination

Tool: Tree Visualizer

Visual Elements:

Key – Bars
Height – Bar
*Height – Disk
*Height – Base
*Color – Bar
*Color – Disk
*Color – Base
*Sort By
Hierarchy Root Level
*Hierarchy Level 2
*Hierarchy Level 3
*Hierarchy Level 4
*Hierarchy Level 5
*Hierarchy Level...

**Figure 5-3** Data Destination Panel of Tool Manager With Tree Visualizer Selected

*Key - Bars* lets you define what the bars shown in the Tree Visualizer main window represent. For example, in a table representing the budget of the 50 United States, the keys could be state names. If the first key is associated with Alabama, the first bar represents the values for Alabama.

*Height - Bar* lets you specify what the bar heights represent. Typically, the higher the bar, the greater the value represented.

*Sort By* lets you specify a column, the values of which are used to sort the layout of the nodes. The sort order defaults to ascending from left to right.

*Hierarchy Root Level* lets you specify how the table from your data source is converted into a hierarchy. The Visual Elements list defaults to six hierarchical levels. If you specify a sixth hierarchy level, the Tree Visualizer automatically adds a seventh. With every extra level you specify, the Tree Visualizer adds another one. You can specify as many hierarchy levels as necessary.

*Height - Disk*—lets you specify what the heights represent for optional disks placed at the same location as the bar. If no mapping is specified, no disks are displayed.

*Height - Base*—lets you specify what the base heights represent. If no mapping is specified, the bar height mapping is used.

*Color - Bar*—lets you specify what the bar colors represent. The specific colors must be assigned via the Tool Manager's Tool Options panel (see "Choosing Colors" and "Using the Color Browser" in Chapter 3).

*Color - Disk*—lets you specify what the disk colors represent. This option has an effect only if the disk height is specified (see "Choosing Colors" and "Using the Color Browser" in Chapter 3).

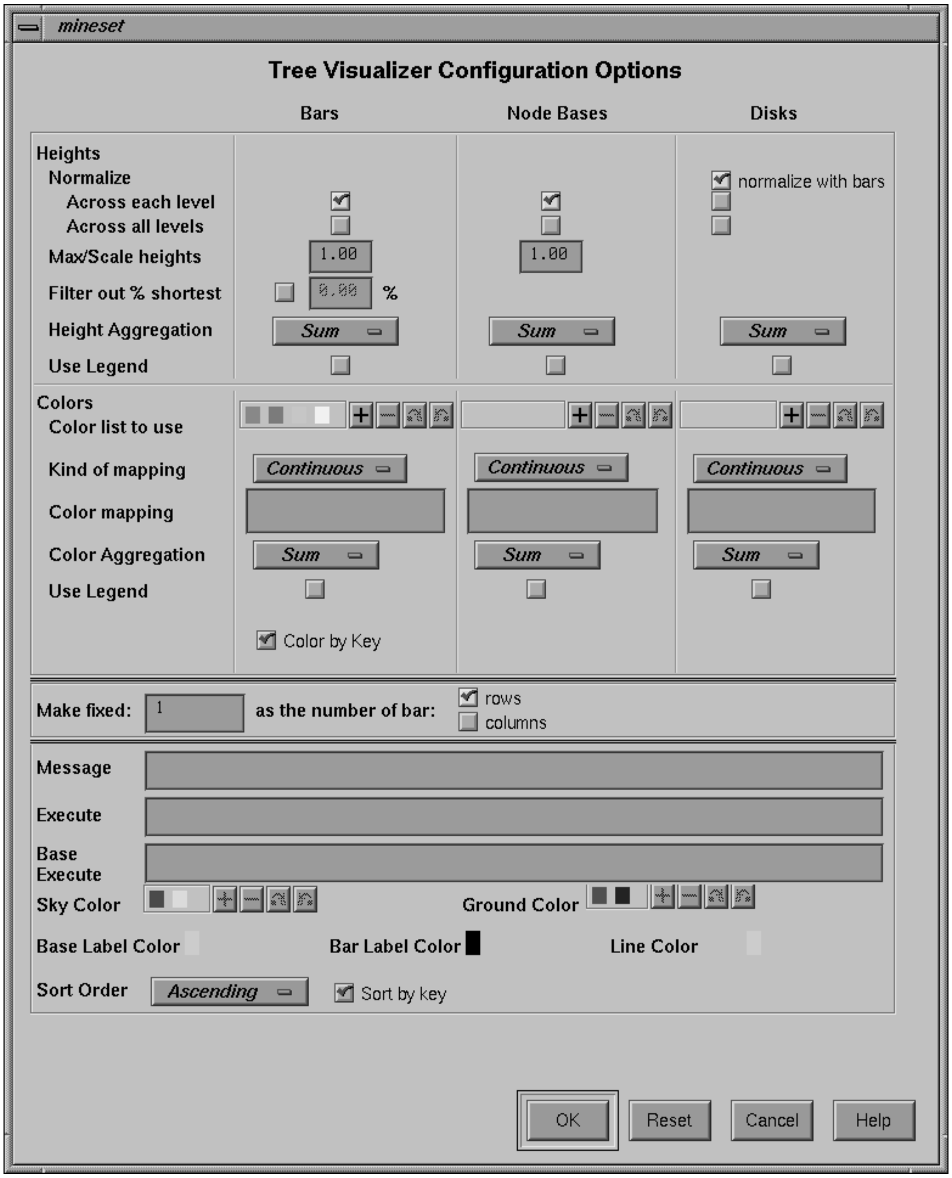
*Color - Base*—lets you specify what the base colors represent. If no mapping is specified, the bar color mapping is used (see "Choosing Colors" and "Using the Color Browser" in Chapter 3).

## Undoing Mappings

To undo any mapping, select that mapping in the Requirements: window, then click the *Clear Selected* button. To undo all mappings, click the *Clear All* button.

## Specifying Tool Options

Clicking the *Tool Options* button causes a new dialog box to be displayed (Figure 5-4). This lets you change some of the Tree Visualizer options from their default values.



mineset

**Tree Visualizer Configuration Options**

| | Bars | Node Bases | Disks |
|---|---|---|---|
| Heights | | | |
| Normalize | | | ☑ normalize with bars |
| Across each level | ☑ | ☑ | □ |
| Across all levels | □ | □ | □ |
| Max/Scale heights | 1.00 | 1.00 | |
| Filter out % shortest | □ 0.00 % | | |
| Height Aggregation | Sum | Sum | Sum |
| Use Legend | □ | □ | □ |
| Colors | | | |
| Color list to use | | | |
| Kind of mapping | Continuous | Continuous | Continuous |
| Color mapping | | | |
| Color Aggregation | Sum | Sum | Sum |
| Use Legend | □ | □ | □ |
| | ☑ Color by Key | | |

Make fixed: 1 as the number of bar: ☑ rows □ columns

Message

Execute

Base Execute

Sky Color

Ground Color

Base Label Color

Bar Label Color

Line Color

Sort Order Ascending ☑ Sort by key

**Figure 5-4** Tree Visualizer's Configuration Options Dialog Box

The top of the dialog box has three columns: *Bars*, *Node Bases*, and *Disks*.

### Normalize Heights

This option lets you normalize heights across each level of the hierarchy (or across all levels) of bars, node bases, and disks. Normalizing the heights determines the maximum value of the height variable; it normalizes all values relative to that height. Thus, if the maximum value is 30.0, and the maximum bar height was set to 1.0 (in arbitrary units), a value of 15.0 would be mapped to a value of 0.5.

Normalizing across each level independently normalizes each level of the hierarchy. This option is most useful if data has been summed up the hierarchy, and prevents the top level of the hierarchy from dwarfing items at the lowest level. Normalizing across all levels normalizes everything together, regardless of the level in the hierarchy. If neither box is checked for bars, no normalization takes place.

Node Bases are normalized independently of Bars. If no boxes are checked, the same normalization method used for bars is used for node bases, although the values are normalized independently.

If disks are present and *normalize with bars* is checked, the disks are normalized in conjunction with the bars: a disk and a bar representing the same value have the same height. If one of the other normalize boxes is checked in the Disks column, disks are normalized independently of the bars: the highest disk and the tallest bar have the same height, regardless of the actual values represented by them.

### Max/Scale Heights

This option lets you specify the height of the tallest bars and node bases. The default is 1.0 (in arbitrary units). If after looking at the view, you see that the heights are too low or too high, use this field to adjust them. For example, entering `2` in the field causes all bars to be doubled in height; entering `.5` makes all bars half as big.

If normalization was specified, this value represents the height of the tallest bar or base. If normalization was not specified, all values are scaled by this amount. The latter can be useful when comparing views of two different datasets.

### Filter out % shortest

This option lets you filter out nodes containing only short bars. First, the tallest bar in the scene is calculated (if heights are normalized by level, then the tallest bar in each level). Then only those nodes that contain at least one bar that is the appropriate percentage of the tallest bar are shown. For example, if you enter 5% in this field, then only those nodes containing at least one bar that is at least 5% of the height of the tallest bar are shown. (Also shown are ancestors of such bars). This option is intended as a coarse way to filter out small, uninteresting nodes. It is not intended as an exact mechanism of identifying specific nodes of a certain value. Use of this option can accelerate the rendering of slow, complex scenes, or reduce clutter resulting from many bars near zero height.

Although small nodes are filtered out, they are nonetheless counted in any cumulation up the hierarchy.

### Height Aggregation

By default, the height of the bars of the parent node is the sum of the height of all the bars of the children; however, these heights can be average, max, min, count, or any of the values that appear. This aggregation can be used for the values of the bar heights, base heights, and disk heights.

### Colors

This set of options lets you

- specify the list of colors to use
- specify the kind of mapping
- map colors to bars, node bases, and disks

To use these Colors options, you must have mapped a column to the *Color - Bar, *Color - Disk, or *Color - Base requirements of the Data Destination panel. See “Choosing Colors” and “Using the Color Browser” in Chapter 3 for a more detailed explanation of how to choose and change colors.

*Color list to use* lets you specify the color list using the + button next to the color list label. This brings up a color editor that lets you specify a color to be added to the list.

*Kind of mapping* lets you specify whether the color change that is shown in the graphic display is *Continuous* or *Discrete*. If you choose Continuous, the color values (of the bars, node bases, or disks) shift gradually between the colors entered in the Color list to use field as a function of the values that are mapped to those colors in the *Color mapping* field. If you choose Discrete, the colors change only at the specified boundaries.

*Color mapping* lets you specify values to which the colors are mapped.

**Example 5-1**

If you

- used the Color Browser to apply red and green to bars
- selected *Discrete* for the *Kind of mapping*
- entered the values `0 100`

then the display shows all bars (or node bases or disks) with values of less than 100 in red, and all those with values greater than or equal to 100 in green.

**Example 5-2**

If you

- used the Color Browser to apply red and green to bars
- selected *Continuous* for the *Kind of mapping*
- entered the values `0 100`

then the display shows all bars (or node bases or disks) with values less than or equal to 0 as completely red, those as greater than or equal to 100 as completely green, and those between 0 and 100 as shadings from red to green.

### Color Aggregation

By default, the values of the colors of the bars of the parent node are the sum of the values of all the bars of the children; however, these colors can be average, max, min, or any of the values that appear. This aggregation can be used for the values of the bar colors, base node colors, and disk colors.

### Color by Key

This option lets you automatically color the bars by their key value. This option is ignored if another coloring was specified. If you specify no color list, or specify insufficient colors, additional colors are chosen at random. If extra colors are specified, they are ignored.

### Make Fixed

By default, this option places all bars across one row. This option allows changing the number of rows or columns. If neither rows nor columns are selected, or the number is set to 0, then neither rows nor columns are fixed, and the closest approximation to a square is displayed.

### Message

This option lets you type in any message you want. The message statement specifies the message displayed when the pointer is moved over an object or when an object is selected. By default, the same message is used for the base as for the bars. If no message is specified, a default message containing the names and values of all the columns is used.

The format of the message must match the type of data being used:

- Strings must use %s.
- Ints must use integer formats (like %d).
- Floats and doubles must used floating-point formats (like %f).

For a detailed description of the message field, see “Message Statements” in Appendix B.

### Execute and Base Execute

These options let you type in a UNIX command that is executed when double-clicking on a bar or base. If only the Execute field is filled in, it applies to both bars and bases. If both are filled in, Execute applies to bars, and Base Execute applies to bases. The format is similar to the message statement. If no execute statement appears, double-clicking has no effect.

For a detailed description of the Execute field, see “The Execute Statement” in Appendix B.

### Sky Color

You can specify either one or two colors. If only one color is specified, the sky is solid. If two colors are specified, the sky is shaded between the colors. When specifying two colors, the first color is for the top of the sky, the second for the bottom.

### Ground Color

You can specify either one or two colors. If only one color is specified, the ground is solid. If two colors are specified, the ground is shaded between the colors. For the ground, the first color is for the far horizon, the second is for the near ground.

### Base Label Color

You can specify the color of the labels on the front of the bases.

### Bar Label Color

You can specify the color of the labels on the front of the bars.

### Line Color

You can specify the color of the lines connecting the bases.

### Sort Order

If you select the *Sort by Key* checkbox, the nodes in the display are in sorted order. The menu next to the checkbox lets you specify whether to sort in ascending or descending order.

### Resetting the Tool Options

If, after you have made changes to the Tool Options dialog box, you want to reset the values of all options to their default values, click the *Reset Options* button.

### Saving the New Tool Options

Once you have finished making changes to the Tool Options dialog box, click *OK* to return to the Tool Manager's main screen.

## Saving Tree Visualizer Settings

The Tool Manager stores information for the Tree Visualizer in several files, all sharing the same prefix:

- *<prefix>.treeviz.data* contains data.
- *<prefix>.treeviz.schema* describes the data file.
- *<prefix>.treeviz* contains information needed by the Tree Visualizer.
- *<prefix>.mineset* contains all the information needed to create the other files.

To specify a prefix, use the *Save Current Session As ...* menu option in the File menu of the Tool Manager's main window. If you do not specify a prefix, it is based on the data source.

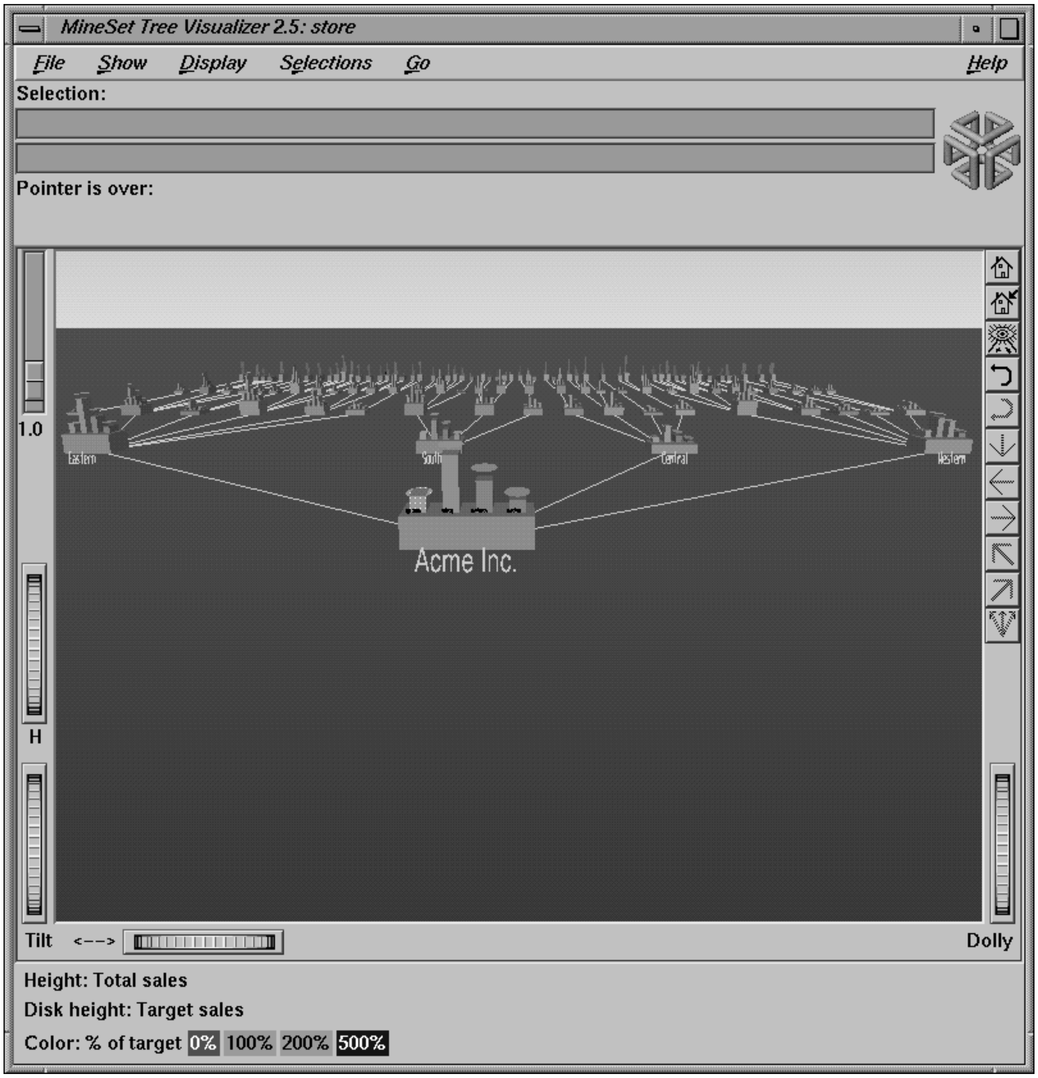
When you use the *Invoke Tool* button, the *.data*, *.schema*, and *.treeviz* files are updated, if necessary.

## Invoking the Tree Visualizer

To see the Tree Visualizer graphically represent your data, click the *Invoke Tool* button at the bottom of the Data Destination panel.

## Working in the Tree Visualizer’s Main Window

A file’s hierarchy is visible only after a valid configuration file is specified. For example, specifying *store.treeviz* results in Figure 5-5.



Height: Total sales

Disk height: Target sales

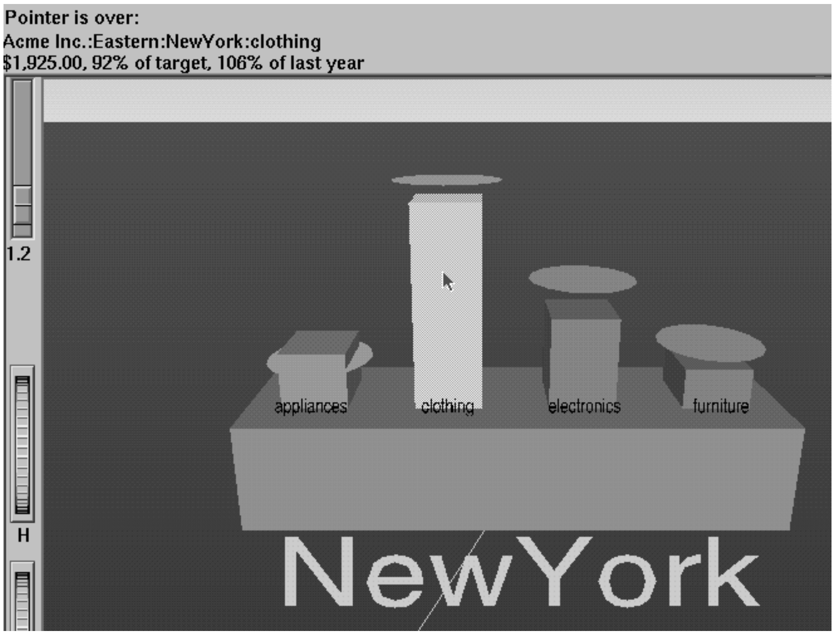
Color: % of target 0% 100% 200% 500%

**Figure 5-5** Tree Visualizer’s Initial View When Specifying store.treeviz

The root node of the hierarchy is at the front of the scene, near the bottom of the Tree Visualizer's main window. In back of the root node are its descendents; each one consists of a base with bars on it. You can change what the heights and colors of the bars represent via the Tool Manager or by manually changing the *.treeviz* configuration file; usually, the base represents the aggregate of all the bars. Bases are connected with lines representing the connection of the nodes to their descendents.

## Highlighting an Object or Node

To highlight an object, move the mouse over that object (either a base or a bar). This causes information about that object to appear over the top left of the view area, under the *Pointer is over:* label (Figure 5-6). To highlight a node and obtain information about that node, place the pointer over a line leading to that node. This information appears in the same place as that for an object.



Pointer is over:
Acme Inc.:Eastern:NewYork:clothing
$1,925.00, 92% of target, 106% of last year

**Figure 5-6** A Highlighted Object and the Information It Represents

## Selecting an Object

To select an object and zoom to it, left-click the mouse on that object. Hold the Ctrl key down while clicking to select the object without zooming to it. At the top of the window, under the label “Selection:”, you see information about a selected object. The information is the same as that shown when highlighting an object. As long as the object is selected, the information is displayed. This lets you compare information about two objects by selecting one, then highlighting the other. Using the mouse, you can cut and paste selection information into other applications, such as reports or databases.

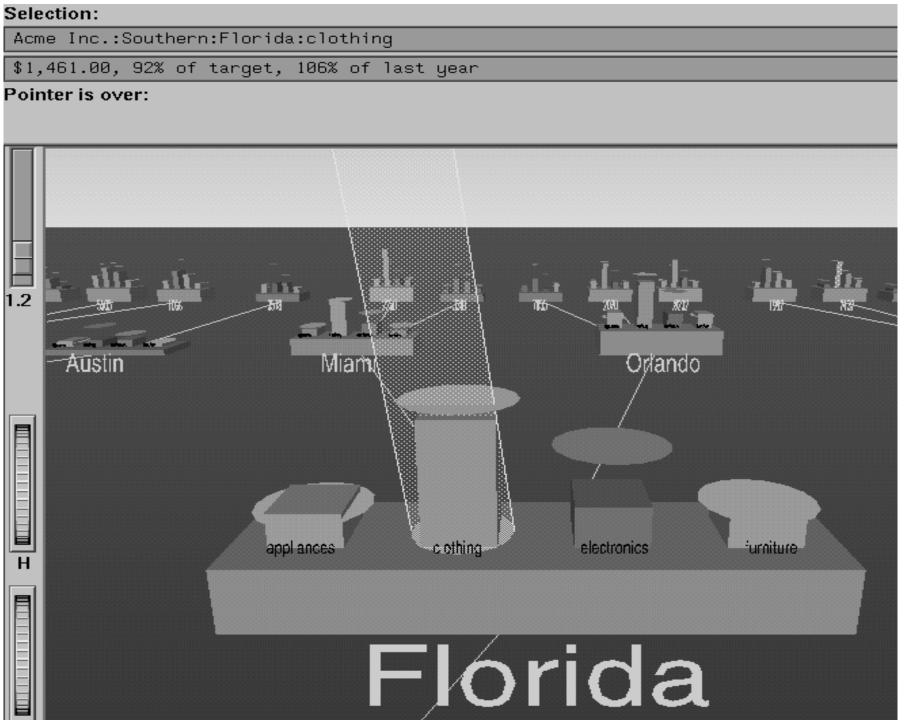
If you hold the Shift key while left-clicking on an object, the selection of that object is toggled. If the object is currently not selected, it then is selected; conversely, if it is currently selected, it then is deselected. Using this technique, it is possible to select multiple objects simultaneously. While the information under the “Selection:” label only shows the information on the last object selected, it is possible to see the values for all selections by using Selections > Show Values or by drilling through to the original data behind the selections (see “The Selections Menu” on page 166).

If an execute statement was specified via Tool Manager or the configuration file, then double clicking on an object executes the appropriate command. If the `-warnexecute` option was specified when invoking the Tree Visualizer, a warning is given first.

## Spotlighting an Object

When you select an object, a white spotlight appears on it (Figure 5-7). A yellow spotlight appears when you are searching (see “The Search Panel” on page 154). Spotlights are visible even if the selected object is a descendent node in the far background.

The edges of spotlights are surrogates for an object: when you move the pointer over the edge of a spotlight, the associated object is highlighted, and information about that object appears above the top left of the view. Left-click the edge of a spotlight to select the associated object and (if the Ctrl key is not held down) to zoom to it. The spotlight is active only on the solid lines along the edges, not the translucent section in the center. This lets you select objects behind the spotlight.



Selection:

Acme Inc.:Southern:Florida:clothing

$1,461.00, 92% of target, 106% of last year

Pointer is over:

**Figure 5-7** Example of a Selected (Spotlighted) Object

## Using the Right Mouse Button

When the cursor is in the main window, clicking the right mouse button (or, if the mouse has been reconfigured, the third button) brings up a menu that lets you select the children of a node. If you click on a node with children, it provides you with a list of the children. This list is displayed as long as you hold the mouse button down. If you do not click on a node, but one is selected, it provides you with a list of children of the selected node. If nothing is selected, or if the selected node has no children, no menu is displayed.

## Navigating With the Middle Mouse Button

To navigate over the scene in the main window, use the middle mouse button. You also can use external controls to perform all middle mouse button functions (see the “External Controls” on page 147).

To move through the main window, click the middle mouse button. A small square appears (see Figure 5-8). Move the cursor out of this square while pressing the mouse to move your point of reference dynamically through the 3D landscape. The farther the cursor is from the square, the faster your viewpoint moves. To move the viewpoint forward, move the mouse up. To move the viewpoint back, move the mouse down. Moving the mouse left and right causes the viewpoint to shift accordingly. You can move in any direction as long as a part of your data is visible.

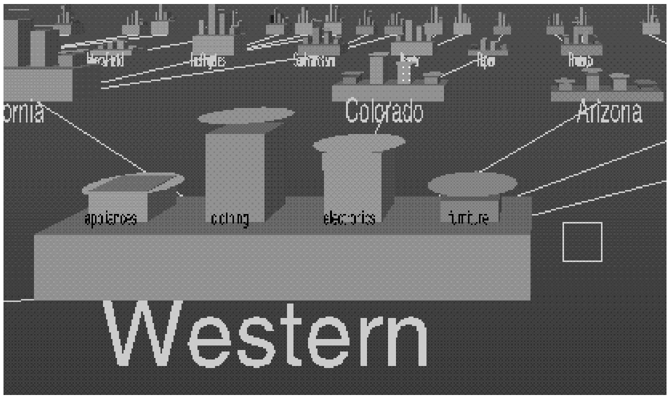


**Figure 5-8** Example of the Square as Navigational Base

To move the viewpoint up and down, hold the Shift key down when pressing the middle mouse button. To move the viewpoint up, move the mouse up. To move the viewpoint down, move the mouse down. You cannot move below ground level.

To combine horizontal and vertical motion (that is, to move the viewpoint back and forth, as well as up and down), hold the Alt key down when pressing the middle mouse button. Note that while moving forward, the viewpoint also moves down, based on the current tilt. Similarly, while moving backward, the viewpoint moves up, based on the tilt.

**Note:** You cannot turn from side to side. Tilting the viewpoint requires using external controls.

## External Controls

Several external controls surround the graphics window. These consist of buttons and thumbwheels.

### Buttons

At the top right of the image area are eleven buttons as shown in Figure 5-9.

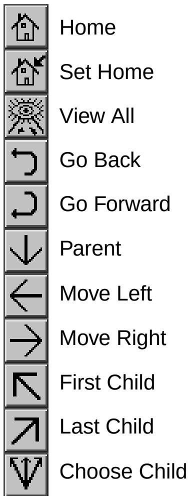


**Figure 5-9** Tree Visualizer's External Button Controls

- *Home* takes you to a designated location. Initially, this location is the first viewpoint shown after invoking the Tree Visualizer and specifying a configuration file. If you have been working with the Tree Visualizer and have clicked the *Set Home* button, then clicking *Home* returns you to the viewpoint that was current when you last clicked *Set Home*.
- *Set Home* makes your current location the Home location. Clicking the *Home* button returns you to the last location where you clicked *Set Home*.
- *View All* lets you view the whole hierarchy, keeping the tilt of the camera. To get an overhead view of the scene, tilt the camera to point straight down, then click the *View All* button. To tilt the camera, see the description of the Tilt thumbwheel (see "Thumbwheels" on page 149).

- *Go Back* lets you return to the previous location. If you have just started the Tree Visualizer and have not moved from the home view, this button is grayed out.
- *Go Forward* lets you proceed to the location from which you clicked the *Go Back* button. If you have not clicked the *Go Back* button, the *Go Forward* button is grayed out.
- *Parent* is active only when you have an object selected. If a bar is selected, clicking this button selects the base containing the bar. If a base is selected, clicking this button moves up the hierarchy to the parent node. Once the root node has been reached (highest level of the hierarchy), the *Parent* button is grayed out. Note that when using *Parent*, the selected node is changed to the parent of the previously selected one.
- *Move Left* lets you select the next sibling to the left. If a bar is selected, the bar to the left of it is selected. If a base is selected, then, if the parent has another child to the left, that is selected. This button is grayed out if nothing is selected, or if the current selection has no sibling to the left.
- *Move Right* lets you select he next sibling to the right. If a bar is selected, the bar to the right of it is selected. If a base is selected, then, if the parent has another child to the right, that is selected. This button is grayed out if nothing is selected, or if the current selection has no sibling to the right.
- *First Child* lets you select the first child of the current node. This button is grayed out if there is no selection, if a bar is selected, or if the current selection has no children.
- *Last Child* lets you select the last child of the current node. This button is grayed out if there is no selection, if a bar is selected, or if the current selection has no children.
- *Choose Child* produces a popup menu that lists all the children of the current node. This button is grayed out if there is no selection, if a bar is selected, or if the current selection has no children.

You also can perform these functions using the *Go* menu (see “The Go Menu” on page 167.)

## Thumbwheels

Four thumbwheels appear around the lower part of the graphics window border (see Figure 5-10). They let you dynamically move the viewpoint.

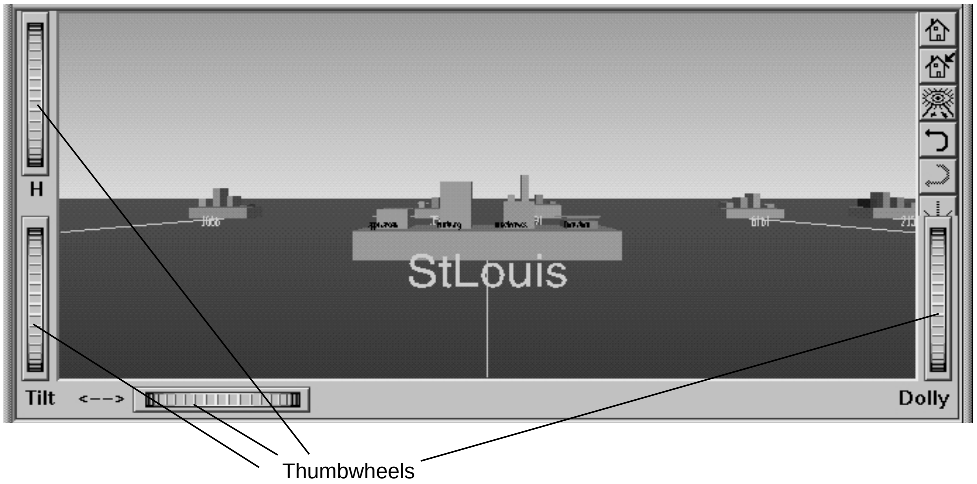


**Figure 5-10** Tree Visualizer's Thumbwheels

- The vertical H (height) thumbwheel, on the upper left, moves the camera up and down. You cannot move the viewpoint below ground level.
- The vertical Tilt thumbwheel, at the bottom left, tilts the camera. You can tilt the viewpoint to any position from straight ahead and straight down. You cannot tilt the viewpoint to look up.
- The horizontal <--> (pan) thumbwheel, at the bottom left, moves the viewpoint from left to right and back. You cannot rotate the viewpoint.
- The vertical Dolly thumbwheel, on the right, moves the viewpoint forward and backward.

### Height Slider

A slider to the top left of the main window (Figure 5-11) lets you rescale all objects in the window. Pushing the slider up to a value of 2.0 doubles the size of all objects in the main window. Pulling the slider back down to a value of 1.0 returns the objects in the window to their original heights.

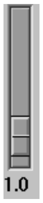


**Figure 5-11** Tree Visualizer's Height Slider

## Pulldown Menus

You also can access all of the Tree Visualizer's functions via five pulldown menus. These are labeled File, Show, Display, Go, and Help.

If you start the Tree Visualizer without specifying a configuration file, only the File and the Help menus are available. The Show, Display, and Go menus are available after a graph is loaded.

## The File Menu

The File menu (Figure 5-12) contains nine options.

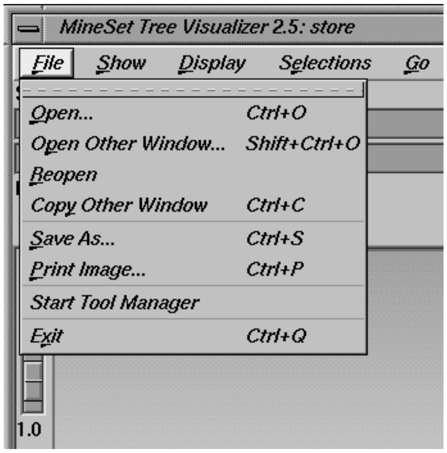


**Figure 5-12** Tree Visualizer's File Pulldown Menu With Options

- *Open* loads and opens a configuration file, displaying it in the main window. Previously displayed data is discarded. Use *Open* to view a new dataset, or to view the same dataset after changing its configuration.
- *Open Other Window* opens a configuration file, but displays its results in a different window. The current dataset remains open.
- *Reopen* reopens the currently opened file. This can be used after the configuration or data file has been updated.
- *Copy Other Window* opens a new window that displays the same view of the current dataset. You can interact with these windows independently.
- *Save As* saves the state of the current Tree Visualizer window into an image file. The user specifies both the file name (default is *treeviz.rgb*), format (default is *rgb*), and whether to save the entire window, including any legends, or just the main scene with the graphical objects (default is the full window).

- *Print Image* outputs the state of the current Tree Visualizer window to a printer. You can specify the output printer using a Print dialog panel (default is your system's default printer) and, like the *Save As* dialog, choose whether to print the entire window or just the main scene window.
- *Start Tool Manager* starts the Tool Manager (if not already running), and restores it to the state it was in when the Tree Visualizer was invoked.
- *Close* closes the current window (and all panels associated with it). If no other windows are open, *Close* exits the application.
- *Exit* closes all windows and exits the application.

## The Show Menu

The Show menu (Figure 5-13) contains four options:

- Overview
- Search Panel
- Filter Panel
- Marks Panel

Each of these options brings up another dialog box for interacting with the data.

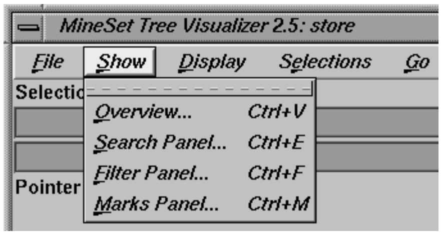


**Figure 5-13** Tree Visualizer’s Show Pulldown Menu With Options

### The Overview Window

Select Overview in the Show menu to bring up a new window with an overhead view of the complete hierarchy (Figure 5-14). If you want the Overview to be brought up automatically each time the scene is viewed, set the Overview option in the configuration file (see "Overview" on page 566).

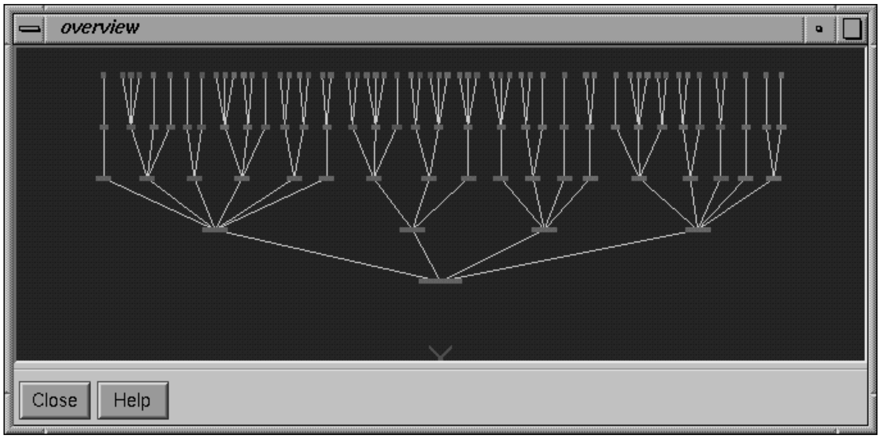


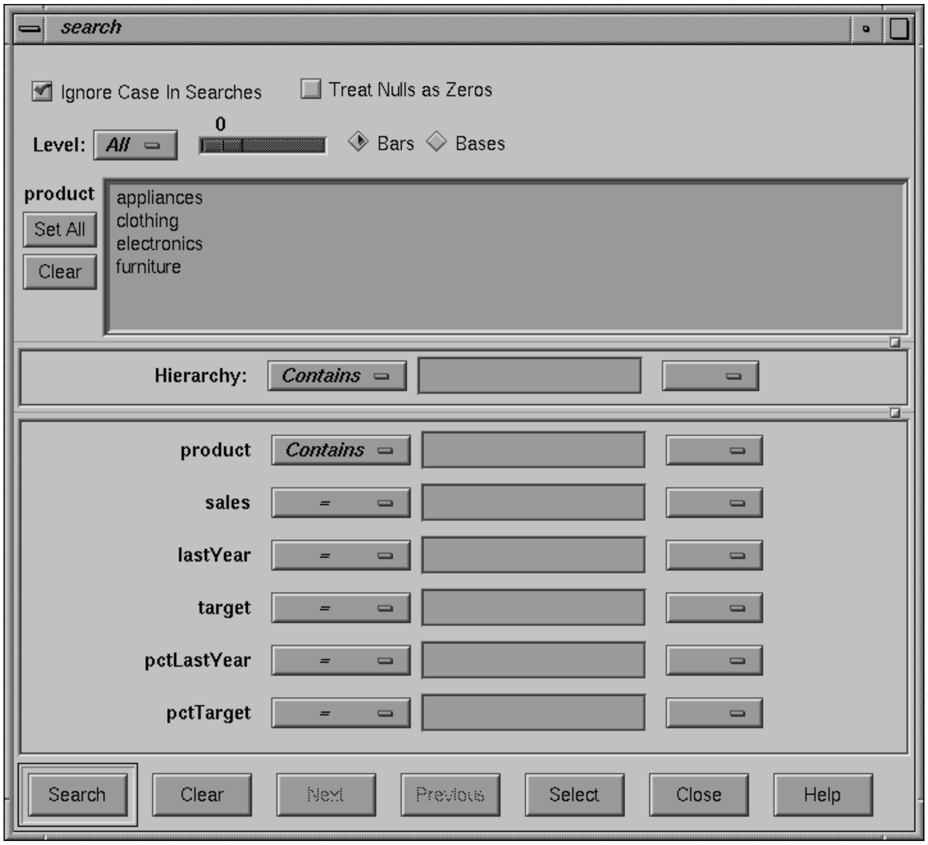
**Figure 5-14** Tree Visualizer's Overview Window

The "X" in the Overview window shows your current location. The Overview helps you keep track of your location and viewpoint in the entire scene. It can also help you quickly go to a specific node.

To select an object in the Overview and have the main view zoom to it, left-click that object. This is similar to left-clicking the object in the main view. Middle-clicking anywhere in the overview zooms your viewpoint to that location, even if no object is at that point.

### The Search Panel

Select *Search* in the Show menu to bring up a dialog box that lets you specify criteria to search for objects (Figure 5-15).



search

☑ Ignore Case In Searches

□ Treat Nulls as Zeros

Level: All

0

◆ Bars ◇ Bases

product: appliances, clothing, electronics, furniture

Hierarchy: Contains

product: Contains

sales: =

lastYear: =

target: =

pctLastYear: =

pctTarget: =

**Figure 5-15** Tree Visualizer's Search Dialog Box

Once the search is complete, yellow spotlights highlight objects matching the search criteria (see Figure 5-16). To display information about an object under a yellow spotlight, move the pointer over that spotlight; the information appears in the upper left corner, under the label *Pointer is over:*. To select and zoom to an object under a yellow spotlight, left-click the spotlight; if you press the Ctrl key while clicking, zooming does not occur.

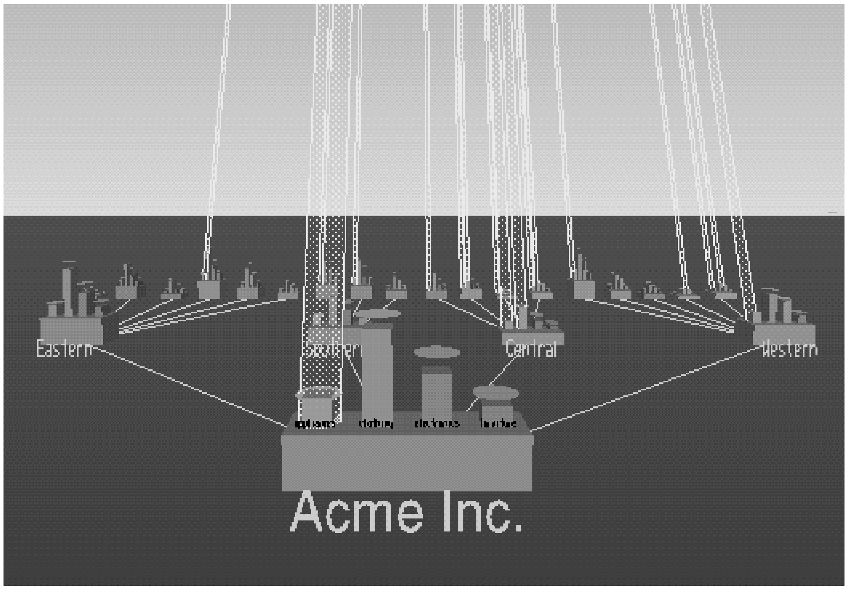


**Figure 5-16** Sample Results of a Search in the Tree Visualizer

### Items in the Search Panel

To specify whether a search is case-sensitive, click the *Ignore Case In Searches* checkbox, at the top of the Search panel. For example, if this toggle is on (a check mark appears on that button), the string “hello” is the same as “HellO.”

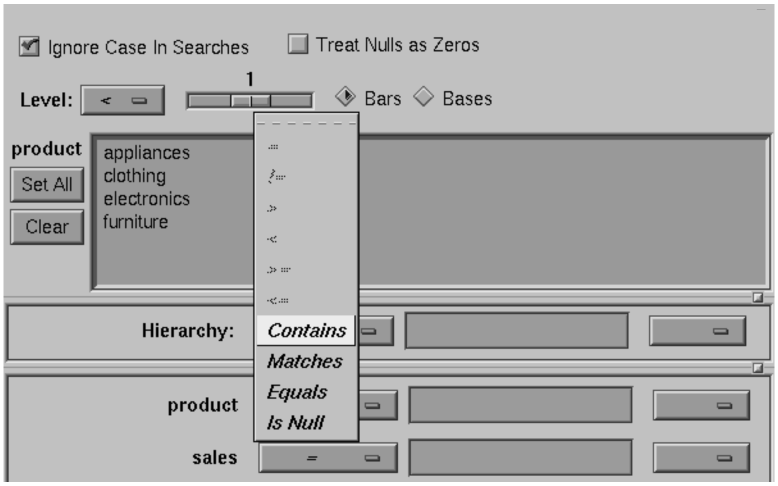
To the right of the case sensitivity checkbox is another, labeled *Treat Nulls as Zeros*. If this checkbox is off (the default), comparisons involving nulls cannot return TRUE in a search. If the it is on, nulls are treated as equal to zero.

Below the case-sensitivity checkbox are controls that let you specify the parts of the hierarchy to be searched. By default, the whole hierarchy is searched. To limit the levels searched, select a relational operator (such as <=) from the option menu that lets you specify the operand for the level. Then use the slider to select the level to be searched. Level 0 is the root of the hierarchy, level 1 is the level below that, and so forth. To search the root and the two levels below that, for example, choose <= 2.

Checkboxes also let you choose whether to search the bars or the bases.

When searching through bars, the default is that all bars are searched. To search only a specific list of bars, you must select them. The *Set All* button turns on all bars; this is useful if most of the bars are to be searched, and only a few are to be turned off. The *Clear* button turns off all bars. If no bar is selected, the bar list is ignored, and all bars are searched.

Below the panel for bar labels is a Hierarchy field that lets you specify nodes to search (Figure 5-17). Below the Hierarchy field are fields that let you specify search criteria for individual columns (defined in the Current Columns: window of the Tool Manager's Table Processing pane, see "Selecting the Tree Visualizer Tool" on page 132).



☑ Ignore Case In Searches ☐ Treat Nulls as Zeros

Level: < ; 1 ; ◆ Bars ◇ Bases

product: appliances, clothing, electronics, furniture

**Figure 5-17** Detail of the Tree Visualizer's Search Dialog Box

To search for numeric values, enter the value, and select a relational operation (=, !=, >, <, >=, <=). To search for alphanumeric values, enter the string for which you want to search. You can use any of three types of string comparisons:

- "Contains" indicates that it contains the appropriate string. For example, California contains the strings Cal and forn.
- "Equals" requires the strings to match exactly.
- "Matches" allows wildcards:
  - An asterisk (*) represents any number of characters.
  - A question mark (?) represents one character.
  - Square braces ([ ]) enclose a list of characters to match.

  For example, California matches Cal*, Cal?fornia, and Cal[a-z]fornia.

In some cases (usually associated with binning in the Tool Manager), an option menu of values appears, instead of a text field. To ignore that variable, select Ignored in the Option menu. You can use relational operators (such as >=) with these options. This means that the specified value as well as subsequent ones are selected.

In addition to numeric and string comparison operations, you can specify `Is Null`, which is true if the value is null.

To the right of each search field is an additional option menu that lets you specify "And" or "Or" options. For example, you could specify "sales > 20 And < 40." You can have any number of And or Or clauses for a given column, but cannot mix And and Or in a single column.

Note that if different levels of the hierarchy are keyed by different types of data (for example, the top level is selected by strings, while the second level is selected by integers), then the "Hierarchy" search field is treated as a string and provides string operations, not number operations.

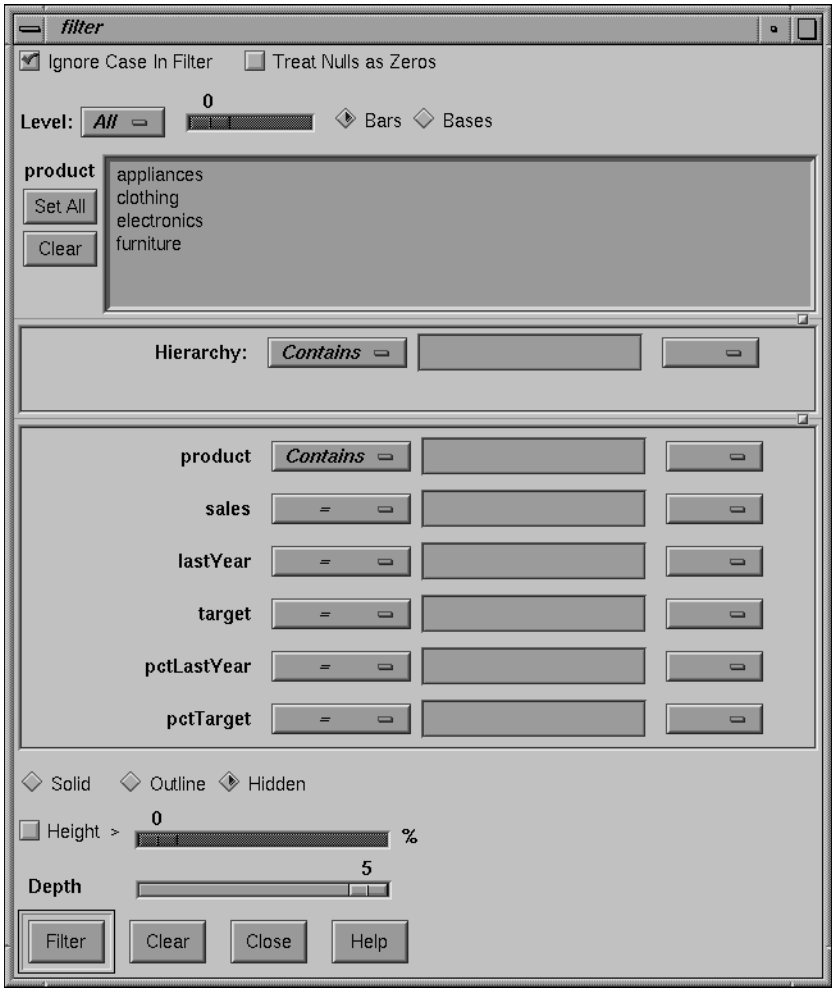
If the *Ignore Case In Searches* checkbox is checked, the comparisons of all string searches are case-insensitive.

Six buttons are placed across the bottom of the Search panel:

- *Search* causes the search to be started. This button is automatically activated if the Enter key is pressed and the panel is active.
- *Clear* turns off all search spotlights and erases the values from the search fields.
- *Next* selects and zooms to the next matched object, in left-to-right order. After the last matched object is selected, clicking *Next* returns the view to the Home position. *Next* is valid only after a search that has found matches.
- *Previous* selects and zooms in the opposite order from that of the *Next* button.
- *Select* causes all objects that matched the search criteria to be selected. The Selections menu can then interact with these objects.
- *Close* closes the search window and turns off the search spotlights. If the Search panel is reopened, it is in the same state as it was before the last *Close*; clicking *Search* again repeats the last search.

### The Filter Panel

The Filter panel filters out selected information, thus fine-tuning the displayed hierarchy. You can use the Filter panel to emphasize specific information, or to shrink the amount of data for better performance. Figure 5-18 shows a sample Filter panel.



filter

☑ Ignore Case In Filter □ Treat Nulls as Zeros

Level: All 0 ◆ Bars ◇ Bases

product

appliances
clothing
electronics
furniture

Hierarchy: Contains

product Contains

sales =

lastYear =

target =

pctLastYear =

pctTarget =

◇ Solid ◇ Outline ◆ Hidden

□ Height > 0 %

Depth 5

**Figure 5-18** Tree Visualizer's Filter Dialog Box

To specify whether a filter is case-sensitive, click the *Ignore Case In Filter* checkbox, at the top of the Filter panel. For example, if this toggle is on (a check mark appears on that button), the string "hello" is the same as "HellO."

To the right of the case sensitivity checkbox is another, labeled *Treat Nulls as Zeros*. If this checkbox is off (the default), comparisons involving nulls cannot return TRUE in a filter. If the it is on, nulls are treated as equal to zero.

Below the case-sensitivity checkbox are controls that let you specify the parts of the hierarchy to be filtered. By default, the whole hierarchy is filtered. To limit the levels filtered, select a relational operator (such as <=) from the option menu that lets you specify the operand for the level. Then use the slider to select the level to be filtered. Level 0 is the root of the hierarchy, level 1 is the level below that, and so forth. To filter the root and the two levels below that, for example, choose <= 2.

Checkboxes also let you choose whether to filter the bars or bases.

When filtering bars, the default is that all bars are filtered. To filter only a specific list of bars, you must select them. The *Set All* button turns on all bars; this is useful if most of the bars are to be filtered, and only a few are to be turned off. The *Clear* button turns off all bars. If no bar is selected, the bar list is ignored.

Filtering bars does not affect the information in the base, which continues to include the summary of all bars.

Below the panel for bar labels is a Hierarchy field, which lets you specify nodes to filter. Below the Hierarchy field are fields that let you specify filter criteria for individual columns (defined in the Current Columns: window of the Tool Manager's Table Processing pane, see "Selecting the Tree Visualizer Tool" on page 132).

To filter for numeric values, enter the value, and select a relational operation (=, !=, >, <, >=, <=). To filter for alphanumeric values, enter the string for which you want to filter. You can use any of three types of string comparisons:

- "Contains" indicates that it contains the appropriate string. For example, California contains the strings Cal and forn.
- "Equals" requires the strings to match exactly.
- "Matches" allows wildcards:
  - An asterisk (*) represents any number of characters.
  - A question mark (?) represents one character.
  - Square braces ([ ]) enclose a list of characters to match.

  For example, California matches Cal*, Cal?fornia, and Cal[a-z]fornia.

In some cases (usually associated with binning in the Tool Manager), an option menu of values appears, instead of a text field. To ignore that variable, select Ignored in the Option menu. You can use relational operators (such as >=) with these options. This means that the specified value as well as subsequent ones are selected.

In addition to numeric and string comparison operations, you can specify `Is Null`, which is true if the value is null.

To the right of each filter field is an additional option menu that lets you specify “And” or “Or” options. For example, you could specify “sales > 20 And < 40.” You can have any number of And or Or clauses for a given column, but cannot mix And and Or in a single column.

Note that if different levels of the hierarchy are keyed by different types of data (for example, the top level is selected by strings, while the second level is selected by integers), then the “Hierarchy” filter field is treated as a string and provides string operations, not number operations.

If the *Ignore Case In Filters* checkbox is checked, the comparisons of all string filters are case-insensitive.

If a node does not meet the filter criteria, has no bars that meet the criteria, and has no children that meet the criteria, the node is not shown. There can be, however, cases in which a specific object meets the filter criteria, but its ancestors up the tree do not. Also, other bars in the same node might not meet the criteria. Since position is important in interpreting context, it might not be good to eliminate those bars. Consequently, you are given an option of selecting one of three radio buttons that control how these objects should be drawn: *Solid*, *Outline*, and *Hidden*. Note, however, that if objects are drawn in a less solid form due to the Display Zeros or Display Null menu, they are displayed appropriately. For example, if Nulls are to be hidden, they are always hidden, regardless of the filter criteria.

The exception to this is when filtering to specific bars. In such a case, the other bars are eliminated and don’t take up space, regardless of the radio button settings.

The Height Filter slider lets you filter out those nodes containing only short bars. The size of a value is shown as a percentage of the maximum height. First, the tallest bar in the scene is calculated (if heights are normalized by level, then the tallest bar in each level). Then only those nodes that contain at least one bar that is the appropriate percentage of the tallest bar are shown.

For example, if you enter 5% in this field, then only those nodes containing at least one bar that is at least 5% of the height of the tallest bar are shown. (Also shown are ancestors of such bars). This option is intended as a coarse way to filter out small, uninteresting nodes. It is not intended as an exact mechanism of identifying specific nodes of a certain value; use the search panel for that purpose. Use of this option can accelerate the rendering of slow, complex scenes, or reduce clutter resulting from many bars near zero height. You can also set this filtering option in the configuration file by using the Height Filter command.

Although small nodes are filtered out, they are nonetheless counted in any cumulation up the hierarchy.

The Depth slider, which is under the Height Filter slider, lets you display the hierarchy so that only a given number of levels are displayed at any given time. When you are at the top of the hierarchy, only the number of hierarchical levels specified by the slider is seen. The nodes in the rows are arranged to optimize their visibility. When navigating to nodes lower in the hierarchy, additional rows are made visible automatically. The nodes above them automatically adjust their locations to accommodate the newly added nodes; thus, some nodes might seem to move. Note that the overview shows all nodes in the hierarchy, not just the top nodes; thus, the layout of the overview might not match the layout of the main view. The X in the overview approximates the corresponding location in the main view; there is no exact mapping between the two layouts.

- Click the *Filter* button to start filtering. If the *Enter* key is pressed while the panel is active, filtering automatically starts.
- Click the *Close* button to close the panel.

### The Marks Panel

The Marks panel, from the Tree Visualizer's Show Pulldown Menu (Figure 5-13,) lets you name and store important locations (viewpoints) so that you can easily and quickly return to them (see Figure 5-19). The location is stored relative to the currently selected object. If no object is selected, the absolute location is recorded.

All marks can be indicated by colored flags in the main view. If the mark represents a selected object, the flag is placed on that object. If it represents an absolute position, the flag is placed at that position. To go to the mark, click the flag. All flags can be turned on and off using the Mark Flags menu entry in the Display menu. (See *Mark Flags* in “The Display Menu” on page 165).

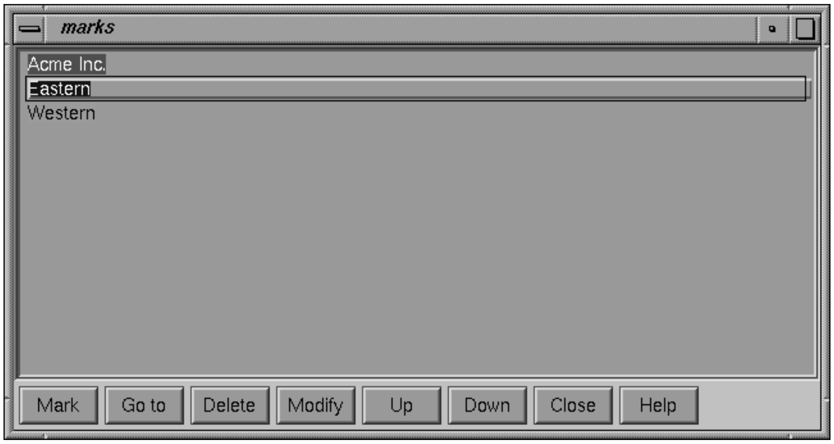
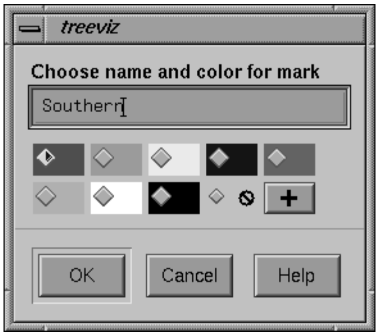


**Figure 5-19** Tree Visualizer's Marks Panel

- Click the *Mark* button to mark the current location. Another dialog box appears (in Figure 5-20) to prompt you for the name and color of the mark. The default name is that of the currently selected object. The color controls the color of the flag appearing in the main window and represents the mark. If you do not want a flag to represent the mark, click the button with the "Not" symbol (slash through a circle). To add another color to the palette, click the button with the plus symbol (+) to bring up a color chooser.



Southern

**Figure 5-20** Window Resulting From Clicking Mark Button

Figure 5-21 shows a sample main window with flags representing the created marks.

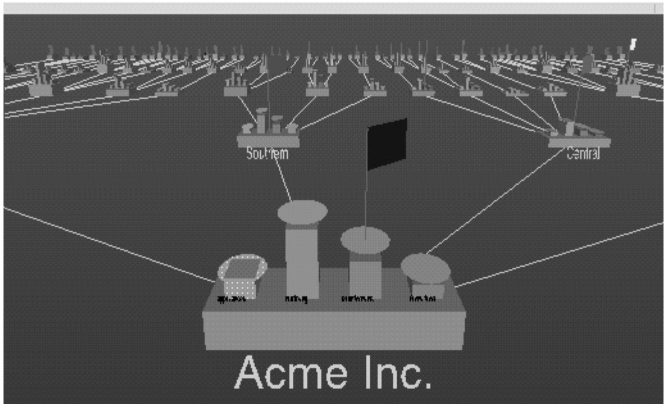


**Figure 5-21** Main Window With Flags Representing Marks

- Click the *Go to* button to go to the current location associated with the selected mark in the panel. Double-clicking a mark has the same effect. If the object selected by that mark no longer exists (because it was filtered out, or the data was changed since the mark was created), the location shown is close to where the object would have been.
- Click the *Delete* button to delete the selected mark in the panel.
- Click the *Modify* button to change the name or color of the selected mark in the panel.
- Click the *Up* button to move the selected mark in the panel up the listing order.
- Click the *Down* button to move the selected mark in the panel down the listing order.
- Click the *Close* button to exit the marks panel.

The file storing the marks information has the same name as the configuration file, with a *.marks* suffix appended. Whenever a mark is changed, all marks are saved to that file. If all marks are deleted, the *.marks* file is removed. If mark changes cannot be saved (because of a permission error, for instance), a warning appears; this warning is not repeated when subsequent mark changes are attempted.

## The Display Menu

The Tree Visualizer's Display menu lets you control several display parameters.

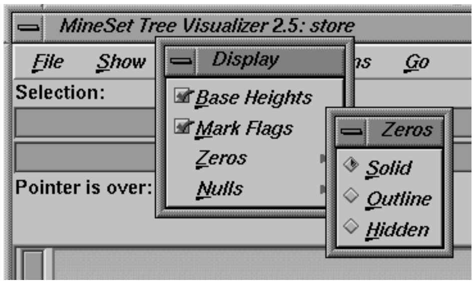


**Figure 5-22** Tree Visualizer's Display Menu

*Base Heights* is a checkbox that lets you turn the heights of the bases on and off. To see negative numbers, or to make it easier to compare the bar heights, turn this option off. Turning it on provides summary information about all the bars. The initial value of this toggle can be changed with the "base height" statement in the configuration file.

*Mark Flags* is a toggle option that lets you turn on or off the flags representing marks (also see "The Marks Panel").

*Zeros* is a submenu that controls how objects with zero height are displayed. By default, they are shown like other objects: a solid cube of height zero (a plane). The submenu lets you specify them to be displayed as outlines (appearing as a hollow square), or to be hidden completely (not drawn). The initial value of this of this can be changed using the "zero" option in the configuration file (see "Zero" on page 568).

*Nulls* is a submenu that controls how objects of null height are displayed. It has the same options as the zero menu; however, the default for null options is to display the objects as an outline. The initial value can be changed using the "null" option in the configuration file (see "Null" on page 569).

## The Selections Menu

The Selections menu lets you drill through to the underlying data. This menu has five items (see Figure 5-23).

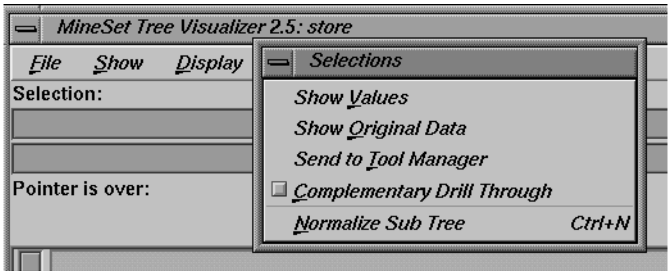


**Figure 5-23** Tree Visualizer's Selection Menu

- *Show Values* displays a table (Record Viewer) of the values for all selected objects.
- *Show Original Data* retrieves and displays the records corresponding to what has been selected. The resulting records are shown in a table viewer.
- *Send To Tool Manager* inserts a filter operation, based on the current box selection(s), at the beginning of the Tool Manager history. The actual expression used to do the drill through is determined by extents of the current box selection(s). If nothing is selected, a warning message appears.
- *Complementary Drill Through* causes the *Show Original Data* and *Send To Tool Manager* selections, when used, to fetch all the data that are not selected.
- *Normalize Subtree* determines the maximum height of the elements in the subtree, and normalizes all values relative to that height.

For further details on drill-through, see Chapter 18, "Selection and Drill-Through."

## The Go Menu

The Go menu duplicates the functions of the buttons on the upper right-hand side of the main window (see Figure 5-24). It also identifies keyboard shortcuts for some functions.

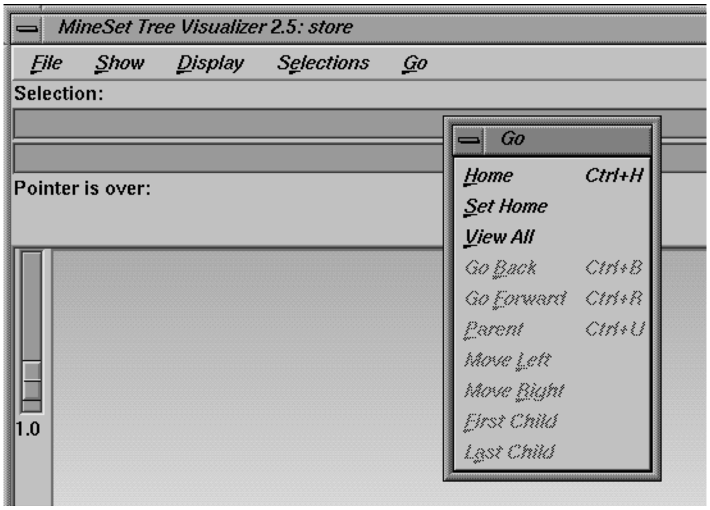


**Figure 5-24** Tree Visualizer’s Go Pulldown Menu

- *Home* takes you to a designated location. By default, this location is the initial view point of the scene. Initially, this location is the first viewpoint shown after invoking the Tree Visualizer and specifying a configuration file. If you have been working with the Tree Visualizer and have clicked the *Set Home* menu item, then clicking *Home* returns you to the viewpoint that was current when you last clicked *Set Home*. The keyboard shortcut for this function is Ctrl+H.
- *Set Home* changes the Home location to your current location. Clicking the *Home* menu item then returns you to the viewpoint that was current when you last clicked *Set Home*.

- *View All* shows the whole hierarchy, keeping the tilt of the camera. To get an overhead view of the scene, tilt the camera to point straight down, then click the *View All* menu item. (To tilt the camera, see the description of the Tilt thumbwheel in “Thumbwheels” on page 149.)
- *Go Back* lets you return to the previous location. If you have just started the Tree Visualizer and have not moved from the home view, this menu item is grayed out. The keyboard shortcut for this function is Ctrl+B.
- *Go Forward* lets you proceed to the location from which you clicked the *Go Back* menu item. If you have not clicked the *Go Back* menu item, the *Go Forward* menu item is grayed out. The keyboard shortcut for this function is Ctrl+R.
- *Parent* is active only when an object is selected. If a bar is selected, clicking this menu item selects the base containing the bar. If a base is selected, clicking this menu item moves up the hierarchy to the parent node. Once the root node has been reached (highest level of the hierarchy), the *Parent* menu is grayed out. The keyboard shortcut for this function is Ctrl+U.
- *Move Left* lets you select the next sibling to the left. If a bar is selected, the bar to the left of it is selected. If a base is selected, then, if the parent has another child to the left, that is selected. This button is grayed out if nothing is selected, or if the current selection has no sibling to the left.
- *Move Right* lets you select the next sibling to the right. If a bar is selected, the bar to the right of it is selected. If a base is selected, then, if the parent has another child to the right, that is selected. This button is grayed out if nothing is selected, or if the current selection has no sibling to the right.
- *First Child* lets you select the first child of the current node. This button is grayed out if there is no selection, if a bar is selected, or if the current selection has no children.
- *Last Child* lets you select the last child of the current node. This button is grayed out if there is no selection, if a bar is selected, or if the current selection has no children.

## The Help Menu

The Help menu (see Figure 5-25) provides access to six help functions.

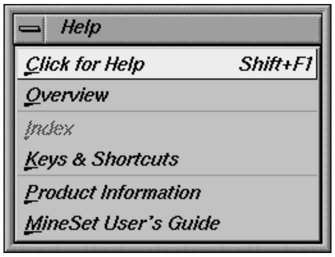


**Figure 5-25** Tree Visualizer's Help Pulldown Menu

- *Click for Help* turns the cursor into a question mark. Placing this cursor over an object in the main window and clicking the mouse causes a help screen to appear; this screen contains information about that object. Closing the help window restores the cursor to its arrow form and deselects the help function. The keyboard shortcut for this function is Shift+F1. (Note that it also is possible to place the arrow cursor over an object and press the F1 function key to access a help screen about that object.)
- *Overview* provides a brief summary of the major functions of this tool, including how to open a file and how to interact with the resulting view.
- *Index* provides an index of the complete help system. This option is currently disabled.
- *Keys & Shortcuts* provides the keyboard shortcuts for all of the Tree Visualizer's functions that have accelerator keys.
- *Product Information* brings up a screen with the version number and copyright notice for the Tree Visualizer.
- *MineSet User's Guide* invokes the IRIS Insight viewer with the online version of this manual.

## Null Handling in the Tree Visualizer

Nulls represent unknown data (see Appendix J, “Nulls in MineSet”).

In the Tree Visualizer, nulls can occur in the following cases:

- The database or data file contains a null value.
- The skipMissing option is not present in the configuration file (see skipMissing in Appendix B,) and data is present for the key value in one node of the hierarchy, but not in another. For example, in a representation of state budgets, if there is no record for state income tax for Texas, Texas would have an income tax of null. This is different than for the case where there is a record showing 0 as the income tax for Texas, in which case it would show a tax of 0.
- When the Tool Manager is used to make an array based on bins and no data falls into a specific bin, the value for that bin is null. For example, if there is no data for 30-40 year olds, that bin is null.
- When making an array in the Tool Manager and the null enum option is specified, an extra array entry, corresponding to the first bar in each bar chart, is created to represent the aggregation of all the values where the bin value is null (see “Aggregations in the Presence of Nulls” in Appendix J). This bar is labeled with a question mark (?), representing null. If there is no data for that null bin, the values associated with it are null as well.

  **Note:** if all values throughout the data associated with the null bin are null, the Tree Visualizer ignores the null bin and does not display it.
- Expressions and aggregations of nulls can generate nulls (see Appendix J).

When a null value is mapped to a visual attribute, special representations are used in the Tree Visualizer. If null is mapped to height, the object is normally drawn in outline mode (although this is configurable through the Display menu (see the “The Display Menu” section) or the configuration file (see “Null” in Appendix B). For a bar or a base, this looks like an empty square. (It does not look like a cube, since it has no height.) For a disk, it looks like a circle. If a null value is mapped to a color, it is drawn in a dark grey (see Figure 5-26).

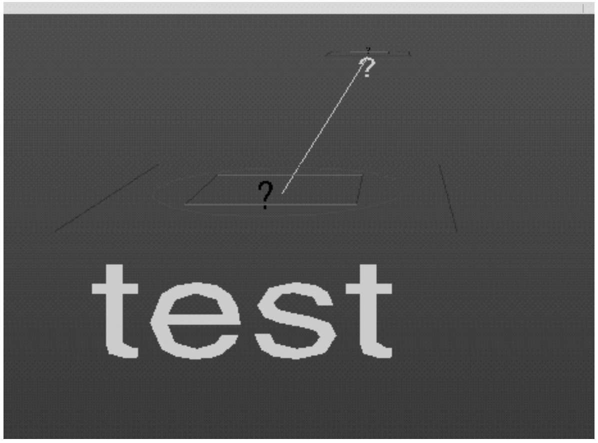


**Figure 5-26** Representation of a Null Value Mapped to Height, Color, Disk, and Label

When selecting an object with a null value, it is shown as a question mark (?) in the selection field.

## Sample Configuration and Data Files

The provided sample configuration and data files demonstrate the Tree Visualizer's features and capabilities. The following files are in the directory */usr/lib/MineSet/treeviz/examples*:

- *store.data* and *store.treeviz*
  When graphically displayed, these files show hypothetical sales data for a store chain. The hierarchy includes the entire chain, regions, states, cities, and individual stores. Four products are shown for each level in the hierarchy. In this configuration, heights represent sales in dollars; colors represent the percentage of the target dollar amount.
- *stateRevenue.data* and *stateRevenue.treeviz*
  When graphically displayed, these files show the revenue components of every state's budgets for 1992, as obtained from the United States Census Bureau (from http://www.census.gov/govs/state/stfin92.dat). Heights represent the dollar amounts in taxes. The descendent nodes in the background show the contribution of various taxes to the total revenues shown in the root node.

- *beer.data* and *beer2.data*, and *beer.treeviz* and *beer2.treeviz*
  When graphically displayed, these files show fictitious data based on consumer research of beer purchases. The hierarchy contains three levels:

  1. The first is category (for example, beer or ale).
  2. The second level is brand codes (randomly assigned).
  3. The third is the individual product codes; for example, twelve-pack versus six-pack (randomly assigned).

  Each chart contains seven bars, representing seven age groups. Bar height represents the total dollars spent by that age group. Colors represent the percentage of dollars spent by males and females. Brands, products, and data used in these files are samples only.

  Both *beer.treeviz* and *beer2.treeviz* produce the same graphical output, but they have been constructed differently. In *beer.treeviz*, each type of beer is represented by a single record, with values for male and for female consumption; these values are stored in an enumerated array (explained in Appendix B, “Creating Data and Configuration Files for the Tree Visualizer”).

  In *beer2.treeviz*, there are seven records for each beer, with each record representing one age group. Note that in the *beer* file, the age groups are represented in the configuration file; in the *beer2* file, they are included in the data file.

  The *beer* file requires less storage space than the *beer2* file; however, the configuration file is a little more complicated. In some cases, it might be easier to produce data in the form used by the *beer2* file.

Additional examples of the Tree Visualizer to visualize a Decision tree are provided in Chapter 11.

*Chapter 6*

# Using the Map Visualizer

This chapter discusses the features and capabilities of the Map Visualizer. It provides an overview of this visualization tool, then explains the Map Visualizer's functionality when working with the following elements:

- main window
- viewing modes
- external controls
- pulldown menus

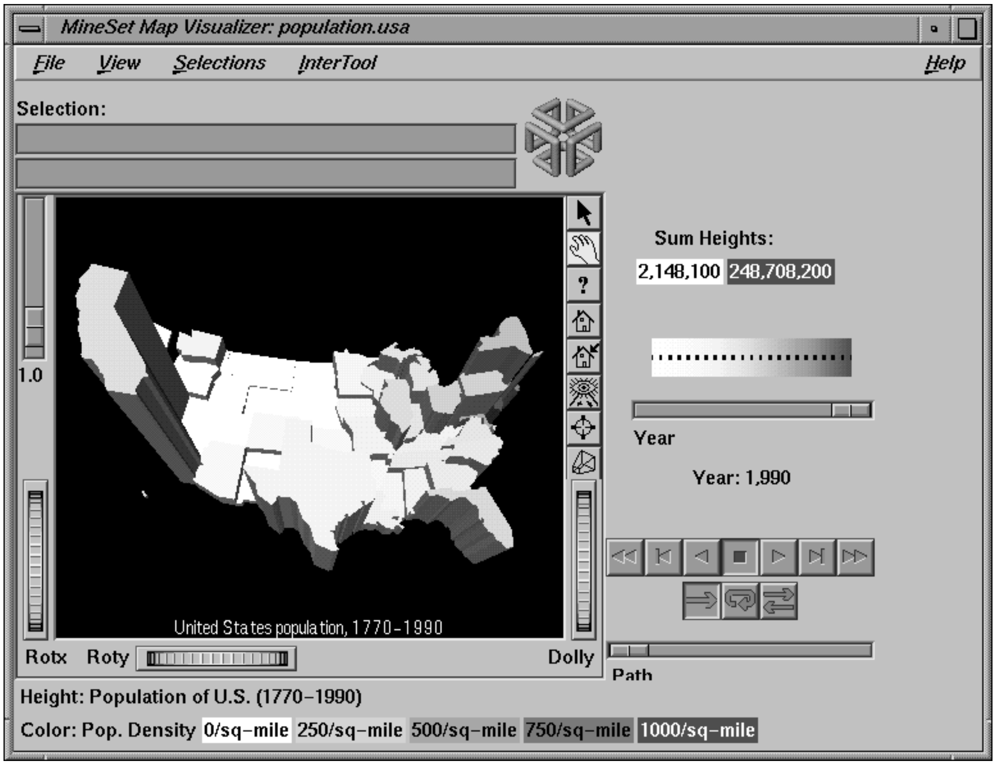
Finally, it lists and describes the sample files provided for this tool.

## Overview of Map Visualizer

The Map Visualizer is a graphical interface that displays data as a three-dimensional "landscape" of arbitrarily specified and positioned "bar chart" shapes. This tool displays quantitative and relational characteristics of your geographically oriented data.

Data items are associated with graphical "bar chart" objects in the visual landscape. However, the objects have recognizable geographical shapes and positions. The landscape can consist of a collection of these geographical objects, each with individual heights and colors (see Figure 6-1). You can dynamically navigate through this landscape by

- panning
- rotating
- zooming to more clearly see areas of interest
- drilling down to see increased granularity of geographic details
- drilling up to aggregate data into coarser-grained graphical objects
- using animation to see how the data changes across one or two independent dimensions.


MineSet Map Visualizer: population.usa
File
View
Selections
InterTool
Help
Selection:
1.0
United States population, 1770–1990
Rotx
Roty
Dolly
Year
Path

Sum Heights: 2,148,100 248,708,200

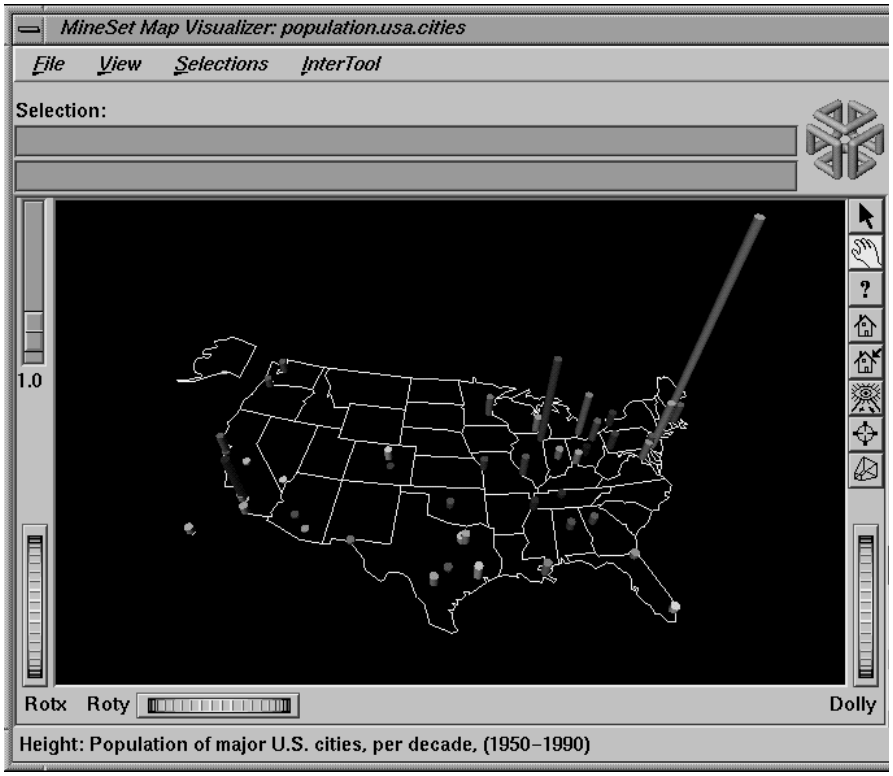
Year: 1,990

Height: Population of U.S. (1770–1990)

Color: Pop. Density 0/sq–mile 250/sq–mile 500/sq–mile 750/sq–mile 1000/sq–mile

**Figure 6-1** Sample Map Visualizer Screen Showing 1990 U.S. Population

The landscape can also consist of a flat plane of these geographical objects drawn as simple outlines, with “bar chart” cylinders placed at specific locations (see Figure 6-2).



Height: Population of major U.S. cities, per decade, (1950–1990)

**Figure 6-2** Sample Map Visualizer Screen Showing Relative Population of Major U.S. Cities

Another landscape possibility is lines with endpoints at specific point locations, all with individual widths and colors (see Figure 6-3). Lines have width and color properties, instead of the height and color properties of the arbitrarily shaped objects and cylinders.

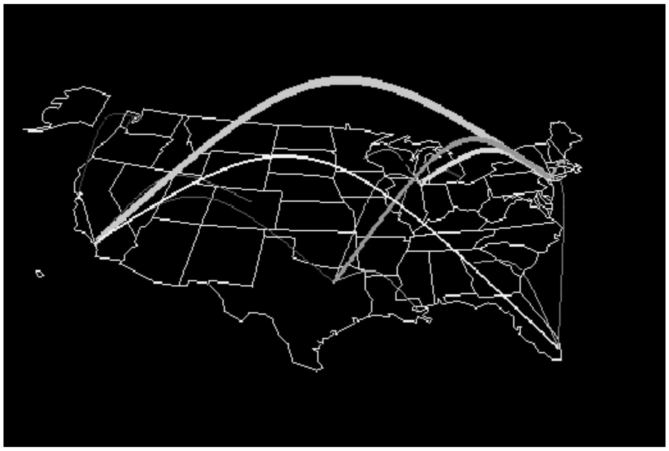


**Figure 6-3** Sample Map Visualizer Screen Showing the United States With Specific Endpoints

## File Requirements

The Map Visualizer requires the following files:

- A data file consisting of rows of tab-separated fields. Typically, the Tool Manager creates this file (see Chapter 3). You can also generate this file without using the Tool Manager (for the required file format, see Appendix C, “Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer”).

  Data files are the result of extracting raw data from a source (such as an Oracle, INFORMIX, or Sybase database) and formatting it specifically for use by the Map Visualizer. Data files have user-defined extensions (the sample files provided with the Map Visualizer have a *.data* extension).

- A gfx file consisting of a description of the shapes and locations of the 1-, 2-, or 3-dimensional objects to be displayed.

  Gfx files must have a *.gfx* extension. MineSet includes various *.gfx* files, including the United States to the granularity of counties, telephone area codes, and postal zip codes, as well as Canada to the granularity of provinces. You can also manually generate *.gfx* files (see Appendix C, “Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer” for the required file format).

- A hierarchy file consisting of a description of
  - the column names of the various graphical objects to be displayed
  - the filenames of the *.gfx* files that describe the locations and shapes of the graphical objects
  - an optional description of the hierarchical relationship of the graphical objects, which is used for the drill-down and drill-up functions.

  Hierarchy files enable drill down and drill up. This means that information associated with objects at one level can be aggregated (or, conversely, shown in greater detail) and displayed at a different level. For example, a hierarchy file defining the relationships between states and regions comprising multiple states allows values such as population levels to be displayed at both the individual state level as well as at regional levels. The *gfx_files/usa.state.gfx* file, for example, describes the shapes of the 50 United States; the *gfx_files/usa.state.hierarchy* file describes the hierarchy grouping individual states into regions, regions into East-West areas, and the East-West areas into an aggregated United States.

  For more information, see Appendix C, "Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer"

- A configuration file describing the format of the input data and how these are to be displayed. Typically, this file is created using the Tool Manager (see Chapter 3). You also can use an editor (such as jot, vi, or Emacs) to produce this file without using the Tool Manager (see Appendix C, "Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer").

  Configuration files should have a *.mapviz* extension. If they do not, they are not listed when selecting the Open option from the File pulldown menu. When starting the Map Visualizer, or when opening a file, specify the configuration file, not the data file.

## Starting the Map Visualizer

There are five ways to start the Map Visualizer:

- Use the Tool Manager to configure and start the Map Visualizer. See Chapter 3 first for details on most of the Tool Manager's functionality, which is common to all MineSet tools; see below for details about using the Tool Manager in conjunction with the Map Visualizer.
- Double-click the Map Visualizer icon, which is in the MineSet page of the icon catalog. The icon is labeled *mapviz*. Since no configuration file is specified, the start-up screen requires you to select one by using File > Open.

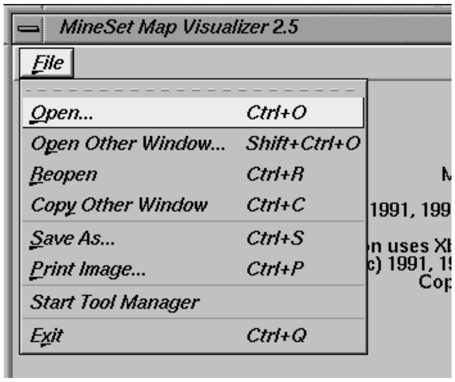


**Figure 6-4** Map Visualizer's Startup Screen, With File Pulldown Menu Selected

Starting the Map Visualizer without specifying a configuration file causes the main window to show the copyright notice for this tool. Only the File and Help pulldown menus can be used. For the main window to be fully functional, open a configuration file by selecting File > Open (Figure 6-4).

- If you know what configuration file you want to use, double-click the icon for that configuration file. This starts the Map Visualizer and automatically loads the configuration file you specified. This only works if the configuration filename ends in *.mapviz* (which is always the case for configuration files created for the Map Visualizer using the Tool Manager).

- Drag the configuration file icon onto the Map Visualizer icon. This starts the Map Visualizer and automatically loads the configuration file you specified. This works even if the configuration filename does not end in *.mapviz*.
- Start the Map Visualizer from the UNIX shell command line by entering this command at the prompt:

  ```
  mapviz [ configFile ]
  ```

  where *configFile* is optional and specifies the name of the configuration file to use. If you don't specify a configuration file, you must use File > Open to specify one (see Figure 6-4).

### Options for Invoking the Map Visualizer

There are a two options that affect how this tool is invoked:

- **`-warnexecute`** indicates that if you attempt to execute a command specified in an execute statement, a warning is displayed and you are given the option to execute the command or not. This is intended for an insecure environment, such as files obtained from the Web, and is used automatically when commands are executed via mtr files.

  You can enable this option permanently by adding the line

  ```
  *minesetWarnExecute:TRUE
  ```

  to your *.Xdefaults* file, or by setting the environment variable

  ```
  MINESET_WARN_EXECUTE
  ```

- **`-quiet`** eliminates the dialogs that popup to indicate progress. You can enable this option permanently by adding the line

  ```
  *minesetQuiet:TRUE
  ```

  to your *.Xdefaults* file.

## Configuring the Map Visualizer Using the Tool Manager

This section describes how the Map Visualizer can be configured using the Tool Manager. Although the Tool Manager greatly simplifies the task of configuring the Map Visualizer, you can construct a configuration file manually for this tool using a text editor (see Appendix C, “Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer”).

Note that the steps required to connect to a data source are described in Chapter 3.

### Generating *.gfx* and *.hierarchy* Files

To use the Map Visualizer, you must provide the application with two files that define the graphical objects to be displayed:

- One or more *.gfx* files, which define the shapes of the graphical objects displayed.
- A *.hierarchy* file, which describes the relationship of multiple, interrelated map (*.gfx*) files.

These files are not created by the Tool Manager; they must already exist as part of MineSet (residing in the */usr/lib/MineSet/mapviz/gfx_files* directory), or they must be created by the user. For instructions on their creation, see Appendix C, “Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer”

The *.gfx* and *.hierarchy* files that are part of the MineSet package include

- the individual states of the United States
- the areas covered by the individual counties of the United States
- the areas covered by the individual five-digit ZIP codes of the United States
- the areas covered by the telephone area codes of the United States
- the individual provinces and territories of Canada
- the individual states of Mexico
- the individual states and territories of Australia
- the individual countries of Western and Central Europe
- regional subdivisions of both France and The Netherlands

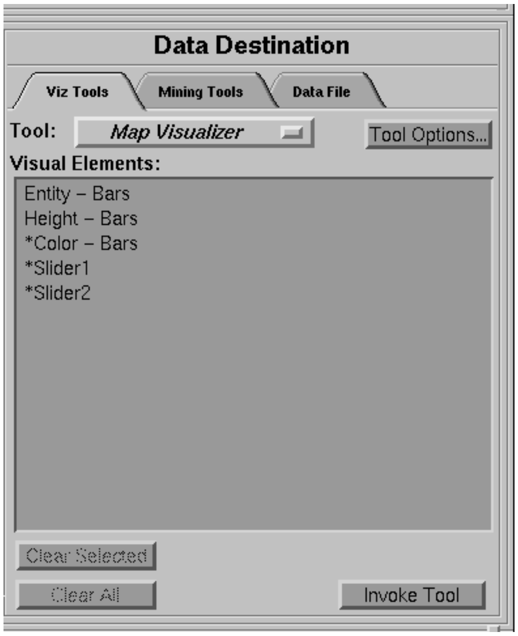
The Map Visualizer requires a data file with

- One column indicating geographical objects (for example, states). Each row in this column must indicate a unique geographical object (staying with the example, this means one row for each state).
- At least one column with numeric values mapped (using arithmetic expressions) to the heights and/or colors of each geographic bar. These columns can be scalar, a 1D array, or a 2D array. If the column is an array, a slider must be used to select specific data points for this mapping to heights and colors.

If both heights and colors are mapped to 1D or 2D arrays, the arrays must have the same indexes (see Appendix C, "Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer").

## Selecting the Map Visualizer Tool

Select the Viz Tools tab in the Data Destination panel of the Tool Manager's main screen (Figure 6-5). From the popup list of tools, select *Map Visualizer*. The window on the right side of this panel displays the mapping requirements for the Map Visualizer. Items in the Visual Elements list that are preceded by an asterisk are optional.



Entity – Bars
Height – Bars
*Color – Bars
*Slider1
*Slider2

**Figure 6-5** Data Destination Panel, With Map Visualizer Selected

- *Entity - Bars* lets you specify which column contains the keywords of the graphical objects.
- *Height - Bars* lets you specify the heights of the geographic bars on the map.
- **Color - Bars* lets you assign the colors of the geographic bars. See “Choosing Colors” and “Using the Color Browser” in Chapter 3 for a more detailed explanation of how to choose and change colors.
- **Slider1* and **Slider2* let you map columns directly to one or two animation Sliders (see “Slider Creation for Mapviz,” below).

## Mapping Columns to Visual Elements

A column in the Current Columns window should be mapped to the Visual Element Height - Bars by clicking the column first, then Height - Bars. Optionally, another column (perhaps even the same column) can be mapped to the Visual Element *Color - Bars. Another column must be mapped to the Visual Element Entity. This must be a string column.

## Undoing Mappings

To undo a mapping, select the mapping in the Requirements: window, then click the *Clear Selected* button. To undo all mappings, click the *Clear All* button.

## Slider Creation for Mapviz

Sliders can be created manually or automatically. The following subsections describe these methods.

### Manual Slider Creation

Tool Manager generates sliders whenever there is an array column present in the current table. The sliders correspond to the indices of the array columns. If the column has one index (one-dimensional array), only one slider is created, but if the column has two indices (two-dimensional array), both an X and a Y slider are created. The current slider indices are indicated in the Tool Options dialog box from the Tool Manager.

Note that for a slider to be created, all array columns in the current table must have the same indices. If array columns with differing indices exist in the current table, no slider is created.

See "Aggregation" in Chapter 3 for more information on creating arrayed columns.

### Automatic Slider Creation

If no arrayed columns are in the current table, Tool Manager can automatically generate sliders by use of the Slider1 and Slider2 mappings. Sliders are created through a combination of automatic binning and aggregation. These automatic operations occur after clicking *Invoke Tool*. The operations do not affect the current history operations of Tool Manager, but they do appear in the configuration files for the tool.

Columns mapped to Slider1 and Slider2 eventually form the indices for the sliders. These columns must be either numeric (int, float, double) or binned. If a column mapped to a slider is already binned, no automatic binning is needed for this column, and this column is used as an index for a slider. However, if the column is not binned, a binned column is created using the automatic binning options in the Tool Options dialog box.

The three methods of binning are:

- Selecting All Distinct Values creates a bin for every unique value of the column.
- Specify the number of bins you want to create. The thresholds for the bins are determined using the Uniform Range approach.
- Selecting Automatic automatically determines the number of bins to create and determines the bin thresholds using the Uniform Range approach.

(See "The Bin Columns Button" in Chapter 3 for more information about binning.) The column used in forming the automatic bins is deleted from the current table.

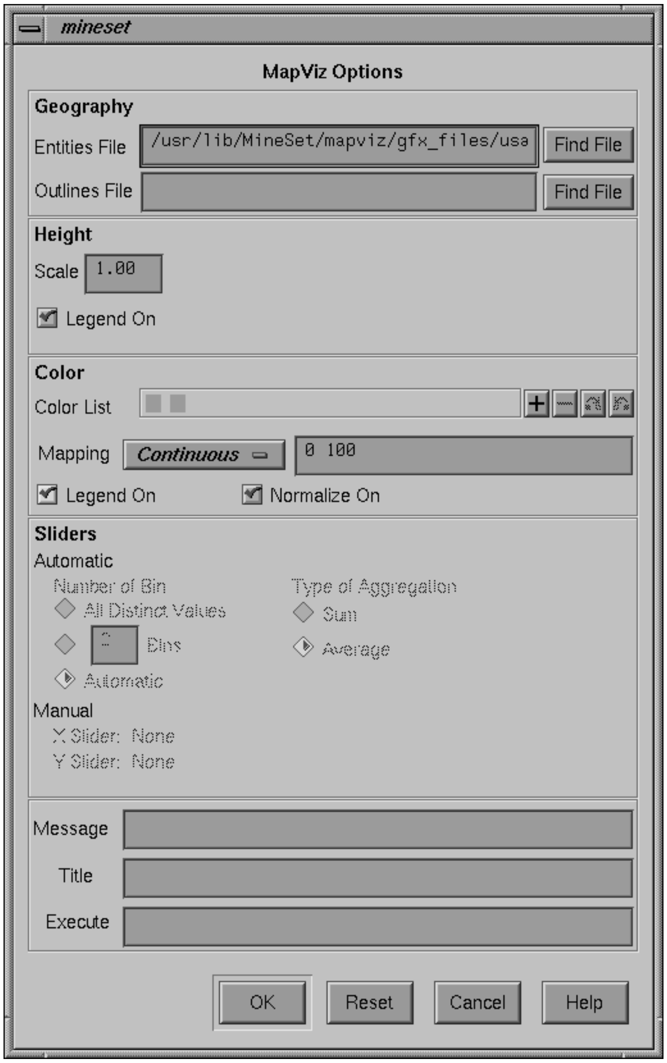
The binned columns now form the indices of array columns. Note that if you want to create only one slider, the index must be mapped to Slider1. Attempting to create only one slider with a mapping to Slider2 is not allowed and generates a Tool Manager error. Also, a column mapped to a slider cannot be mapped to any other mapping, since it is removed during the aggregation process.

Once the slider indices are formed, the arrayed columns are created. This is done using automatic aggregation. Any numeric columns mapped to Height or Color are aggregated using the automatic aggregation options in the Tool Options dialog box. You can either specify aggregating by Sum or by Average. The binned columns created from the slider mappings form the indices for the aggregation. The column mapped to Entity is the only Group-By column. Any remaining columns in the table are removed. (See "Aggregation" in Chapter 3 for a description of the aggregation process.)

The aggregation step automatically forms the arrayed columns used for sliders. These arrayed columns form the new tool mappings. For example, if the column "mpg" were mapped to Height, a new column "avg_mpg[]" is formed and remapped to Height. The progress of the automatic slider generation is displayed in the Tool Manager status window.

## Specifying Tool Options

Clicking the *Tool Options* button causes a new dialog box to be displayed (Figure 6-6). This lets you change some of the Map Visualizer options from their default values.



mineset

MapViz Options

Geography

Entities File: /usr/lib/MineSet/mapviz/gfx_files/usa

Outlines File:

Height

Scale: 1.00

☑ Legend On

Color

Color List

Mapping: Continuous 0 100

☑ Legend On ☑ Normalize On

Sliders

Automatic

Number of Bin

○ All Distinct Values

○ Bins

● Automatic

Type of Aggregation

○ Sum

● Average

Manual

X Slider: None

Y Slider: None

Message

Title

Execute

**Figure 6-6** Map Visualizer's Options Dialog Box

The following sections describe the buttons and fields of the Map Visualizer's Options dialog box.

### Geography

The *Entities File* specifies a *.hierarchy* file to be used for the representation of the geographical "entity" objects, in the Map Visualizer's main window.

The *Outlines File* specifies outline objects to draw, which appear as a flat plane on which the 3-D entity objects are placed.

The *Find File* button lets you browse your files to find the *.hierarchy* file to be used.

Note that the *Entities File* and *Outlines File* fields are optional. If the Entities File is not supplied, then the Map Visualizer creates graphical entity objects consisting of simple rectangles that are arbitrarily sized and placed in the scene.

### Height

This section specifies an initial height *Scale* value (default is 1.0) and whether to display a height legend at the bottom of the Map Visualizer window.

### Color

To use these Color options, you must have mapped a column to the **Color - Bars* requirement of the Data Destination panel. See “Choosing Colors” and “Using the Color Browser” in Chapter 3 for a more detailed explanation of how to choose and change colors.

*Color List*—You can specify the color list using the + button next to the color list label. This brings up a color editor that lets you specify a color to be added to the list.

*Mapping*—You can specify whether the color change that is shown in the graphic display is *Continuous* or *Discrete*. If you choose *Continuous*, the color values shift gradually between the colors entered in the “Color List” field as a function of the values that are mapped to those colors in the “Mapping” field.

The field to the right of the popup button lets you enter specific values to which the colors are mapped. You must have the same number of values in this field as there are colors entered in the “Color list to use” field.

**Example 6-1**

If you

- used the Color Browser to choose gray and red
- selected *Discrete* for the Mapping
- entered the values `0 150000`

then the display shows the population of the United States across the time period 1770-1990. States with more than 150,000 square miles are shown in red, the rest are in gray.

**Example 6-2**

If you

- used the Color Browser to choose gray and red
- selected *Continuous* for the *Mapping*
- entered the values **`0 300000`**

then the display shows the population of the United States across the same time period. The states' colors vary from gray to red, depending on their size; the largest states are shown with the greatest density of red.

You can enter as many colors into this field as necessary for your display. If the number of values in the column that maps to *Color - Bars exceeds the number of distinct colors you have chosen, the Map Visualizer adds an appropriate number of randomly chosen colors at runtime.

*Legend On*—lets you determine whether a color legend is displayed or hidden.

*Normalize On*—lets you determine whether the Map Visualizer automatically scales the colors between the color column's minimum and maximum values (this is called color normalization), as opposed to you manually specifying threshold values. When *Normalize On* is enabled, the threshold values must lie within the range 0 to 100, representing a percentage of the color column's minimum to maximum numeric range.

### Sliders

You can manually select a binned column to be associated with the slider(s), where the binned column indexes an aggregated array that is mapped to height or color. Alternatively, you can have the Tool Manager automatically perform the binning and aggregations. For more details on the Slider options, see “Slider Creation for Mapviz” on page 183.

### Message Field

This lets you specify the message displayed when an entity is selected. For a listing and description of format types that can be entered in this field, see the “Message Statement” section in Appendix C, “Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer”

### Title field

This lets you specify a string that appears at the bottom of the Map Visualizer main window. This string must be enclosed in double-quotes.

### Execute Field

This option lets you type in a UNIX command that is executed when double-clicking on an entity. The format is similar to the message statement. If no execute statement appears, double-clicking has no effect.

For a detailed description of the Execute field, see “Execute Statement” in Appendix C.

### Resetting the Tool Options

If, after making changes to the Tool Options dialog box, you want to reset the values of all options to their default values, click the *Reset Options* button.

### Accepting the Tool Options

Once you have finished making changes to the Tool Options dialog box, click *OK* to return the Tool Manager’s main screen.

### Saving Map Visualizer Settings

The Tool Manager stores information for the Map Visualizer in several files, all sharing the same prefix:

- *<prefix>.mapviz.data* contains data.
- *<prefix>.mapviz.schema* describes the data file.
- *<prefix>.mapviz* contains information needed by the Map Visualizer.
- *<prefix>.mineset* contains all the information needed to create the other files.

To specify a prefix, use the *Save ...* menu option in the File menu of the Tool Manager's main window. If you do not specify a prefix, it is based on the data source.

When you use the *Invoke Tool* button, the *.data*, *.schema*, and *.mapviz* files are updated, if necessary.

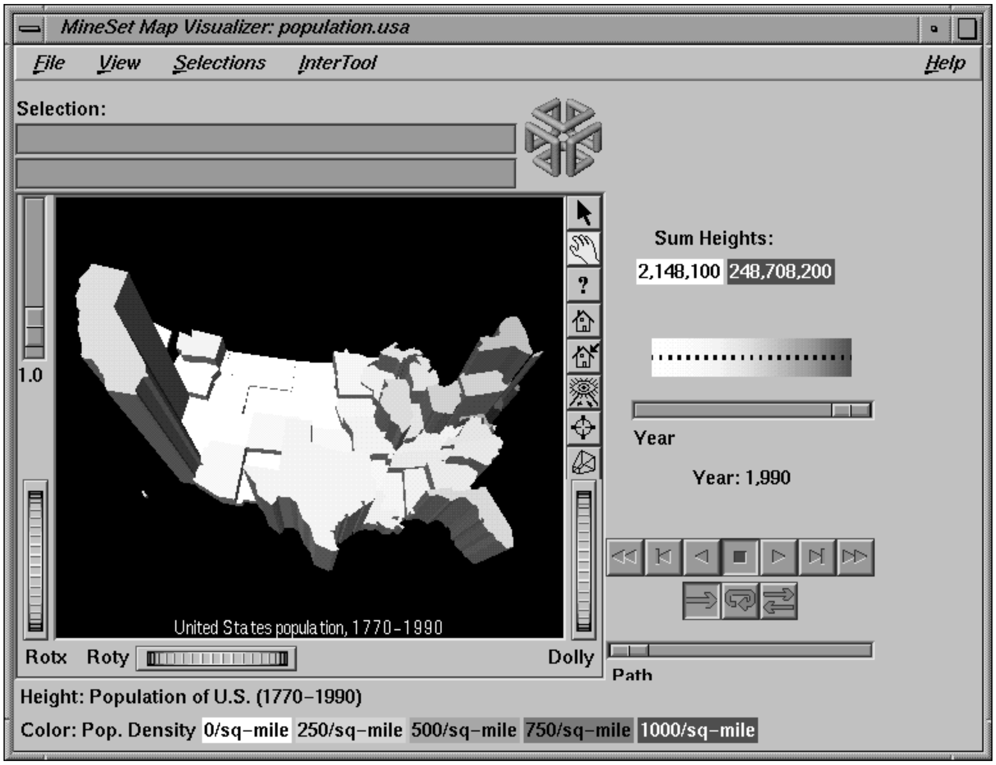
### Invoking the Map Visualizer

To see the Map Visualizer graphically represent your data, click the *Invoke Tool* button at the bottom of the Data Destination panel.

## Working in the Map Visualizer's Main Window

If you started the Map Visualizer without specifying a configuration file, the main window shows the copyright notice for the Map Visualizer. Only the File and Help pulldown menus can be used. For the main window to show all menus and controls, open a configuration file. Use File > Open (Figure 6-4) to see a list of configuration files.

When a valid configuration file has been specified, its geographical landscape is visible. For example, Figure 6-7 shows the results of specifying *population.usa.mapviz* and moving the *Year* slider to the far right.


MineSet Map Visualizer: population.usa
File
View
Selections
InterTool
Help
Selection:
1.0
Rotx
Roty
Dolly
Year
Path
United States population, 1770-1990

Sum Heights:
2,148,100 248,708,200

Year: 1,990

Height: Population of U.S. (1770–1990)

Color: Pop. Density 0/sq–mile 250/sq–mile 500/sq–mile 750/sq–mile 1000/sq–mile

**Figure 6-7** Population.usa.mapviz Example With the Slider Moved to 1990

This shows the population and population density for each state of the United States. The population of each state is represented by the height of the state's graphical shape. Heights are relative to each other across the entire range of the animation controls.

## Viewing Modes

The two modes of viewing are *grasp* and *select*. To toggle between these modes, move the cursor into the main window, and press the Esc key. You can also change from one mode to the other by clicking the appropriate button: to enter select mode, left-click the arrow button (to the top-right of the main window); to enter grasp mode, left-click the hand button (immediately below the arrow button, near the top right of the main window).

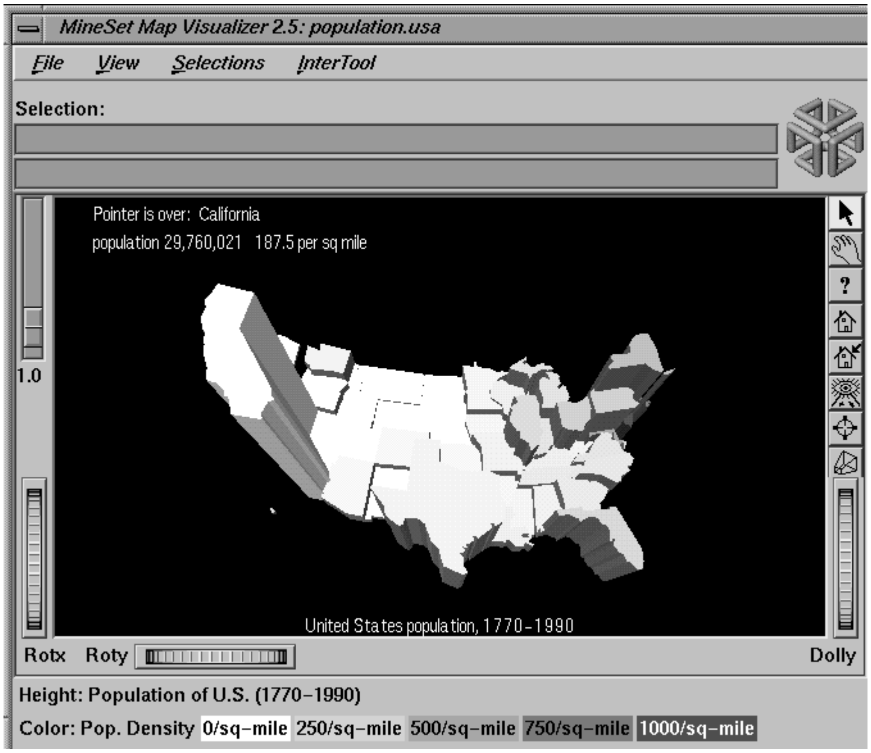
### Grasp Mode

In grasp mode, the cursor appears as a hand. This mode supports panning, rotating, and scaling the scene's size in the main window.

- To pan the display, press the middle mouse button and drag it in the direction you want the display panned.
- To rotate the display, press the left mouse button and move the mouse in the direction you want to rotate.
- To move the viewpoint forward, press the left and middle mouse buttons simultaneously and move the mouse downwards. To move the viewpoint backward, press the left and middle mouse buttons simultaneously and move the mouse upwards. This is equivalent to the functions provided by the Dolly thumbwheel.

### Select Mode

In select mode, you can highlight an object by positioning the cursor over that object. Information about that object then appears at the top of the view area. This information remains visible in the window only as long as the pointer cursor remains over the object. If you position the pointer cursor over an object and click the left mouse button, the same information appears in the Selection Window, which is above the main window, under the "Selection" label (Figure 6-8).



Pointer is over: California
population 29,760,021 187.5 per sq mile

United States population, 1770-1990

Height: Population of U.S. (1770–1990)

Color: Pop. Density 0/sq–mile 250/sq–mile 500/sq–mile 750/sq–mile 1000/sq–mile

**Figure 6-8** Highlighted Information in the Viewing Window and Selected Information

This Selection information remains visible until you select another object or click the background. Using the mouse, you can cut and paste this text into other applications, such as reports or databases.

### Drilling Down and Drilling up

To view a finer level of geographical granularity for an object (if the *.data* and *.hierarchy* files support it), click the right mouse button while the cursor is over that object. This is called "drilling down." You can repeat this down to the finest level of granularity supported by the data. If the cursor is positioned over a specific object when drilling down, only the more detailed sub-objects of that object appear. If, instead, the cursor is positioned on the background at the time of the mouse click, then the more detailed sub-objects of the entire set of objects appear. This might produce a display with a large number of individual objects. The greater the number of objects, the longer the Map Visualizer takes to construct the scene, and the slower the performance when moving the animation controls.

To move up one level and view a coarser geographical granularity ("drill up"), click the middle mouse button. If the cursor is positioned on the background when you click, all the higher-level objects appear. If the cursor is positioned on a specific object in the scene, then the scene "returns" to the group of higher-level objects visible when you last drilled down with the right mouse button.

If an execute statement was specified via Tool Manager or the configuration file, then double clicking on an object executes the appropriate command. If the `-warnexecute` option was specified when invoking the Map Visualizer, a warning is given first.

**Note:** By default, the Map Visualizer initially displays objects at the lowest level of detail; thus, initially, only drill-up (to coarser granularity) is active.

## External Main Window Controls

Several external controls surround the graphics window. These consist of buttons, sliders, and a summary window. Each of these controls is described in this section.

### Buttons

At the top right of the image area are 11 buttons (see Figure 6-9).

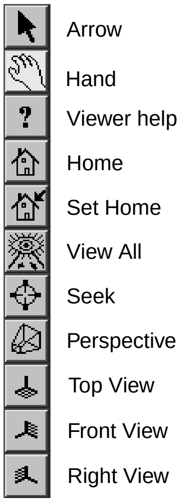


**Figure 6-9** Detail View of Top Right Buttons

- *Arrow* puts you in select mode, which lets you highlight entities in the main window. When in this mode, the cursor shape is an arrow.
- *Hand* puts you in grasp mode, which lets you rotate, zoom, and pan the display in the main window. When in this mode, the cursor shape is a hand.
- *Viewer help* brings up a help window describing the viewer itself.

- *Home* takes you to a designated location. Initially, this location is the first viewpoint shown after invoking the Map Visualizer and specifying a configuration file. If you have been working with the Map Visualizer and have clicked the *Set Home* button, then clicking *Home* returns you to the viewpoint that was current when you last clicked *Set Home*.
- *Set Home* makes your current location the Home location. Clicking the *Home* button returns you to the last location where you clicked *Set Home*.
- *View All* lets you view the entire graphic display, without changing the angle of view you had before clicking on this option. To get an overhead view of the scene, rotate the camera so that you are looking directly down on the entities, then click the *View All* button.
- *Seek* takes you to the point or object you click after selecting this button.
- *Perspective* is a toggle button that lets you view the scene in 3D perspective (closer objects appear larger, farther object appear smaller). Clicking this button again turns 3D perspective off. If *Perspective* is off, the Dolly thumbwheel becomes the Zoom thumbwheel
- *Top View* lets you view the scene from the top.
- *Front View* lets you view the scene from the front.
- *Right View* lets you view the scene from the right side.

## Height-Adjust Slider and Label

To the left of the Map Visualizer's main window is a vertical height adjust slider and, below it, a label containing a numeric value between 0.1 and 100. This slider lets you change the absolute heights of all the graphical objects in the main window. Moving the slider up increases the heights of the objects; moving it down decreases their heights. The numeric value in the label changes accordingly. This value indicates the height multiplier, the default value of which is 1.0. The height adjust slider is useful for accentuating relative height differences between objects in the view window.

### Thumbwheels

Three thumbwheels appear around the lower part of the main window border (see Figure 6-10). They let you dynamically move the viewpoint.

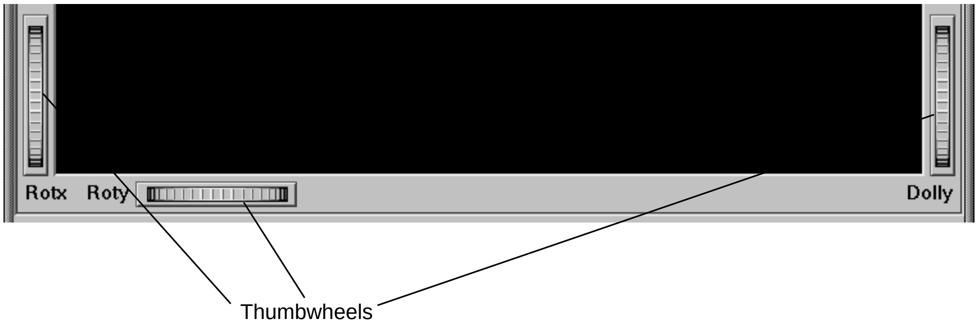


**Figure 6-10** Lower Half of Window With Thumbwheels

- The vertical thumbwheel *Rotx* (rotate about the x axis), on the left, rotates the display up and down.
- The horizontal thumbwheel *Roty* (rotate about the y axis), at the bottom left, rotates the scene in the main window around its centerpoint left and right.
- The vertical *Dolly* thumbwheel, on the right, moves the viewpoint forward and backward. Note that as you use the Dolly thumbwheel to magnify the scene in the main window, additional detail can appear. This is not the case with the Zoom slider, which merely enlarges the scene without adding detail.

## The Animation Control Panel

To the right of the Map Visualizer's main window are several external controls, depending on the type of data being displayed (see Figure 6-11). These controls can include

- sliders for independent dimensions
- a summary window containing a color density profile.
- a color legend showing the color density value limits
- buttons and sliders for animation

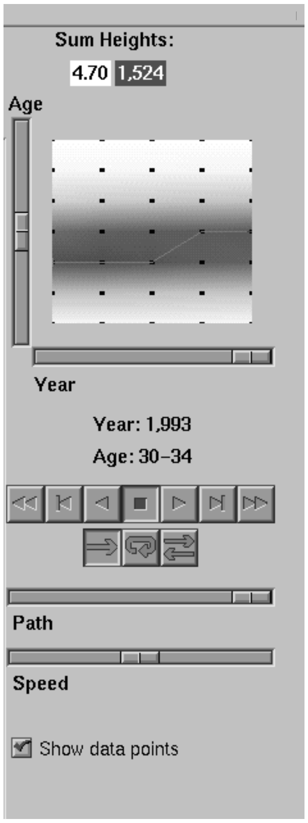


**Figure 6-11** Map Visualizer’s Summary Window With Slider and Animation Controls

## Sliders Controlling Independent Dimensions

The number of sliders appearing adjacent to the summary window is dependent on the dataset displayed in the Map Visualizer’s main window. Datasets can have two, one, or no independent dimensions.

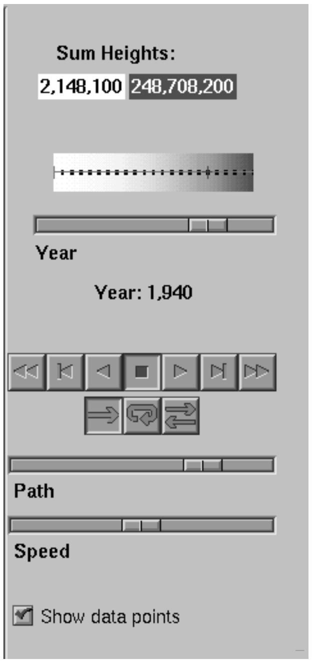
### Datasets With Two Independent Dimensions

If the dataset has two dimensions of independently varying data (such as *nl.births.mapviz*), the animation control panel to the right of the main graphics window becomes visible (as in Figure 6-11).

Within this animation control panel are the 2D summary window and two sliders. The summary window has a horizontal slider below it for selecting data points of the first independent dimension, and a vertical slider to the left for selecting data points of the second independent dimension. The horizontal slider's dimension is identified by a label below it. The vertical slider's dimension is identified by a label above it.

### Datasets With One Independent Dimension

For datasets with one independent dimension (such as *population.usa.mapviz*), only the slider below the summary window appears, and the summary window is compressed (see Figure 6-12). This slider's dimension is identified by a label below it.



Sum Heights:

2,148,100 248,708,200

Year

Year: 1,940

Path

Speed

☑ Show data points

**Figure 6-12** Map Visualizer's Summary Window With One Slider and Animation Controls

### Datasets With No Independent Dimension

For datasets with no independent dimensions (such as *population.europe.mapviz*), no animation control panel appears (see Figure 6-13).

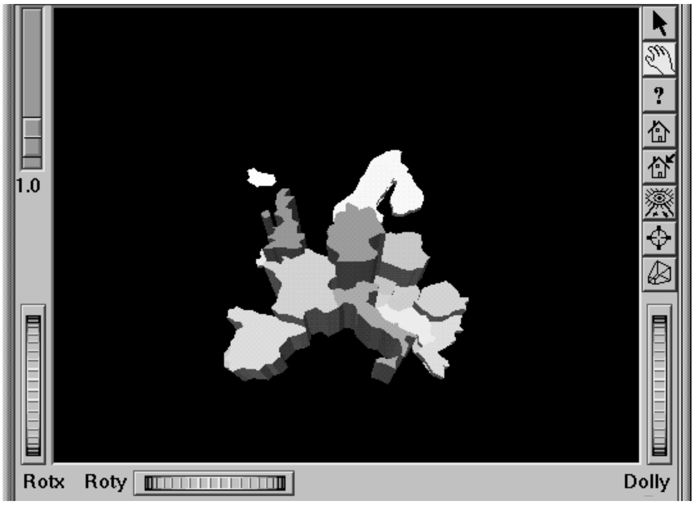


**Figure 6-13** If There Are No Independent Dimensions, No Animation Control Panel Appears

## The Summary Window

The summary window provides a 2D representation of the aggregation of values that the main window displays in 3D. Above this window is a label, Sum Heights, followed by two rectangles: the first white, the second red. Within the rectangles are numbers; each is the respective value for the maximum density of that color. This summary color legend provides a visual and numeric comparison to the densities in the summary window.

The whiter the areas of the summary window, the lower the total values represented by the heights of the objects in the main window. The greater the density of red shown in areas of the summary window, the higher the total of those values. The density of these colors in the summary window provides a summary of the data across the one or two independent dimensions in the dataset, which is useful for guiding your exploration through the data.

By default, the summary window also contains a set of black dots, evenly spaced across the one or two dimensions of data. These dots indicate the precise positions of the discrete datapoints of the data. You can turn off the dots using the View > Show Data Points menu option.

### Color Density Examples in the Summary Window

After opening the *population.usa.mapviz* file, for example, the 2D summary window shows a color range from white (on the left) to red (on the right). White corresponds to the low aggregate population in the early years of the United States; red represents the higher aggregate population in later years. In this example, the greater the density of red, the higher the total population of United States.

For a more complex example, open *perhouse.perage.mapviz*. This dataset has two independent dimensions: time and age. The summary window displays these dimensions as a complex pattern of colors. Place the cursor on the horizontal lines with the greatest density of red, which runs horizontally across the summary window (this means the age group making the greatest number of purchases). Click the left mouse button. The information displayed in the field below the horizontal slider shows that this represents purchases made by 30- to 39-year-olds.

Now place the cursor at the junction of the densest red horizontal (age group) and vertical (time frame) parts of the summary window, and click the left mouse button. The information displayed in the field below the horizontal slider shows that most purchases were made by 30- to 39-year-olds in May-June 1989 and May-June 1990.

### Creating a Path in the Summary Window

If the dataset loaded into the Map Visualizer has at least one independent dimension, it is possible to view all or any part of that dataset via animation. This is done by first creating a path in the summary window, then activating the animation controls described in the next section.

The three ways to draw a path in the summary window are as follows:

- Define a starting point by clicking and holding down the left mouse button, then draw a path by dragging the cursor over the window. The actual path passes through intermediate discrete points closest to the path of the mouse. End the path by releasing the left mouse button.
- Define a starting point by clicking the left mouse button, then define an endpoint by moving the cursor to another part of the window and clicking the middle mouse button. A path appears between those two endpoints, passing through the intermediate discrete data point(s) that are closest to the hypothetical straight line between the endpoints. To add more line segments, continue with repeated middle mouse clicks.
- Define a starting point by clicking the left mouse button, then drag one of the independent dimension sliders to draw a straight line along this dimension. If there are two sliders, then using the second slider will continue to draw a straight line along the axis controlled by this second slider.

The path you draw can only go through the well-defined discrete data points, identified by the black dots in the summary window.

## Animation Buttons and Sliders

Use the seven VCR-like buttons and two sliders (*Path* and *Speed*) below the 2D summary window to control animation.

### Animation Buttons

Once a path is drawn in the summary window (see “Creating a Path in the Summary Window,” above), you can use the VCR-like buttons to control animation along this path. The middle *Stop* button is highlighted in blue to indicate an initial state. Use the adjacent *Play Forward* button (to the right of *Stop*) or *Play Reverse* (to the left) to begin simple movement along the drawn path in a forward or reverse direction. *Forward* and *Reverse* are defined by the sequence in which the path was drawn, not by a sense of left-to-right or right-to-left movement.

To stop and restart the animation, click the *Stop* button, then use the *Play Forward* or *Reverse* button. When you use the *Stop* button, the animation continues in the current direction until the position falls on a discrete data point.

Adjacent to the *Play* buttons are the *Single-Step* buttons, also *Forward* and *Reverse*. Clicking one of these buttons causes the current path position to change to the next discrete data point.

On the outside are the *Fast Forward* and *Fast Reverse* buttons. Clicking one of these *Fast* buttons while in *Stop* state changes the path position to the end (for *Forward*) or to the beginning (for *Reverse*) of the path. Clicking a *Fast* button when in *Play* state increases the animation speed.

### Animation Flow

Below the Animation Buttons are the three Animation Flow buttons.

*Play-once* (default)**—**the animation moves either forward or in reverse until it reaches the end of the path, then stops.

*Loop***—**when the animation reaches the end of the path, it automatically resets to the beginning and starts over again.

*Swing***—**when the animation reaches the end of the path, it reverses direction and retraces its path to the other end; upon reaching that end, the animation reverses direction again, beginning the cycle again.

### Animation Sliders

While animation is stopped, you can move the *Path* slider to reset the position along the path. Note that when you use the Path slider, the cursor in the summary window moves across the drawn path, and the 1D sliders (below and to the left of the drawing area) move consistently with the cursor position. Then use the *Play* or *Reverse* button to restart the animation from the newly specified point.

You can drag the *Path* slider to an arbitrary position on the path between discrete data points; however, when you release the slider, the path position changes to a stop at the nearest discrete data point.

Use the *Speed* slider to adjust the speed of the animation along the path.

### Data Points and Interpolation

As animation proceeds, the variables mapped to height and color in the Map Visualizer also change. However, the variables displayed in the *Selection:* message box show only the data values of the nearest discrete data position, not intermediate (interpolated) data values.

The animation is produced in the following manner: Assume you have data for 10 years, on a per-year basis (that is, 10 data values) and that these correspond to the height of one state in the Map Visualizer. The years are 1991 to 2000, the height for 1991 is 20, and the height for 1992 is 40. As you move the year slider from 1991 to 1992, the height changes by being uniformly interpolated between 20 and 40. For example, midway between 1991 and 1992, the height appears to be 30. As you approach 1992, the height approaches 40. However, you cannot stop an animation between discrete data points, and you cannot drag the *Path* slider to a stationary position between discrete data points.

The data points in the summary window represent the slider positions corresponding to the actual data from the data file. For example, the heights 20 and 40 are representations of actual data, but the height 30 is not. In this example, there would be data points in the summary window at the slider positions corresponding to each year.

Note that not all variables are required to vary with a slider. For example, in the Map Visualizer, the area and name of the state do not vary with the slider (for example, year). If there are two sliders, some variables can vary with only one of the sliders, while other variables vary with both.

## Pulldown Menus

Five pulldown menus let you access additional Map Visualizer functions. These are labeled File, View, Selections, InterTool, and Help. If you start the Map Visualizer without specifying a configuration file, only the File and the Help menus are available. The View menu is available after a valid dataset is loaded.

### The File Menu

The File menu is the same for all visualization tools; see “The File Menu” in Chapter 5.

### The View Menu

The View menu (Figure 6-14) contains six options. This section describes those options below.

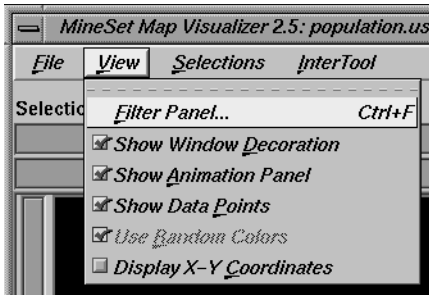
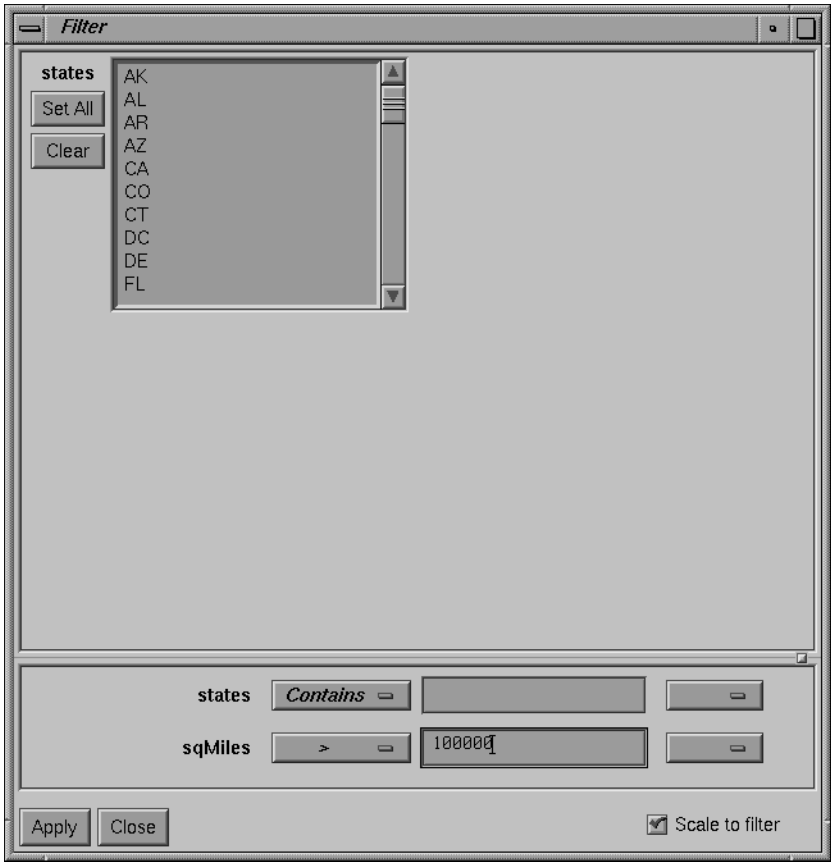


**Figure 6-14** Map Visualizer’s View Pulldown Menu

*Filter Panel* brings up a filter panel (Figure 6-15), which lets you reduce the number of entities displayed in the main viewing area, based on one or more criteria. You can use the filter panel to fine-tune the display, emphasize specific information, or simply shrink the amount of information displayed. *Scale to Filter* lets you specify whether the heights of the graphical objects are scaled across the entire dataset or just across the filtered data.



states Contains

sqMiles > 100000

**Figure 6-15** Map Visualizer Filter Panel

The filter panel has two panes. The top pane lets you filter based on string variables. To select all values of a variable, click *Set All*. To clear the current selections, click *Clear.* To select a value, click it. To deselect a value, simply click it again.

The bottom pane lets you filter based on the values of both string and numeric variables. Only variables whose values do not change as you navigate the slider can be used in filtering.

To filter numeric values, enter the value, and select a relational operation (=, !=, >, <, >=, <=). To filter alphanumeric values, enter the string. You can use any of three types of string comparisons:

- Contains indicates that it contains the appropriate string. For example, California contains the strings Cal and forn.
- Equals requires the strings to match exactly.
- Matches allows wildcards:
  - An asterisk (*) represents any number of characters.
  - A question mark (?) represents one character.
  - Square braces ([ ]) enclose a list of characters to match.

For example, California matches Cal*, Cal?fornia, and Cal[a-z]fornia.

In some cases (usually associated with binning in the Tool Manager), an option menu of values appears, instead of a text field. To ignore that variable, select *Ignored* in the Option menu. You can use relational operators (such as >=) with these options. This means that the specified value as well as subsequent ones are selected.

In addition to numeric and string comparison operations, you can specify `Is Null`, which is true if the value is null.

To the right of each field is an additional option menu that lets you specify "And" or "Or" options. For example, you could specify "sales > 20 And < 40." You can have any number of And or Or clauses for a given variable, but cannot mix And and Or in a single variable.

Click the *Apply* button to start filtering. If you press *Enter* while the panel is active, filtering starts automatically.

Click the *Close* button to close the panel.

- *Show Window Decoration* causes the buttons around the main window to be displayed. Default for this option is on. Toggle this option to make the window decoration disappear.
- *Show Animation Panel* causes the animation control panel to be displayed to the right of the main view. Click this option again to deselect it. When this option is deselected, the animation panel is not displayed. Not displaying the animation panel can be useful when you have applied the InterTool menu's *Synchronize All Mapviz Sliders* option (described in the "The InterTool Menu" on page 209) and need only a single animation control panel on the screen.

- *Show Data Points* causes a grid of black dots to appear (or disappear) in the 2D summary window. Each dot denotes the precise position of a discrete data value in the input dataset. For example, if the input dataset has 10 data values across one independent dimension, then you see heights and colors of the graphical objects in the main window vary continuously, based on data values that are interpolations between these discrete data points. These data point dots in the summary window help you better understand when the heights and colors are derived directly from the input data values, and when they are derived indirectly from interpolated values.
- *Use Random Colors* causes the configuration file's color mapping specifications (for example, white-to-red shadings representing population density) to be ignored. Random, constant colors are assigned to the graphical objects. Click this option again to deselect it.
- *Display X-Y Coordinates* puts the Map Visualizer into a special mode that lets you identify X-Y vertex pairs at specific points of the scene in the main window. In this mode, the Map Visualizer resets the cursor to select mode and displays 3D objects as flat background lines. Clicking the left mouse button on various parts of the displayed scene causes the corresponding X-Y vertex pair values to appear in the Selection Details window. You can also enter the vertex pair points into the *.gfx* file to identify point objects or the endpoints of line objects for subsequent display. Note that displaying X-Y coordinates is used for developing and refining *.gfx* files, not for data analysis.

  When *Display X-Y Coordinates* mode is initially enabled, or when a point in the background is selected, the selection window shows the minimum and maximum X-Y pairs of the currently displayed image in the main window. Add these two value pairs to the new *.gfx* file you are generating. The first record in the file *gfx_files/usa.cities.gfx* shows an example of how the min-max pairs of the *usa.sates.gfx* file were entered into the associated *usa.cities.gfx* file. This ensures that the X-Y coordinate pairs in *usa.cities.gfx* share the same coordinate system as the X-Y coordinate pairs in *usa.sates.gfx*.

## The Selections Menu

The Selection menu lets you drill through to the underlying data. The menu has six items.

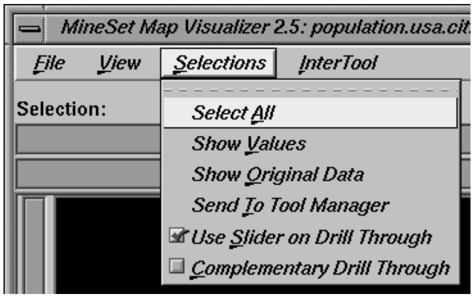

MineSet Map Visualizer 2.5: population.usa.cit
File
View
Selections
InterTool
Selection:
Select All
Show Values
Show Original Data
Send To Tool Manager
☑ Use Slider on Drill Through
□ Complementary Drill Through

**Figure 6-16** Map Visualizer Selections Menu

- *Select All* performs the equivalent of selecting (with the mouse pointer) all the visible graphical objects in the current scene.
- *Show Values* displays a table (Record Viewer) of the values for all selected objects.
- *Show Original Data* retrieves and displays the records corresponding to what has been selected. The resulting records are shown in a table viewer.
- *Send To Tool Manager* inserts a filter operation, based on the current box selection(s), at the beginning of the Tool Manager history. The actual expression used to do the drill through is determined by extents of the current box selection(s). If nothing is selected, a warning message appears.
- *Use Slider On Drill Through* determines whether or not to use the slider position when creating the drill-through expression. If checked (default), an additional term is added to the drill-through expression, limiting the drill-through to those records defined by the slider's position. If this option is not checked, no such limiting term is added.
- *Complementary Drill Through* causes the *Show Original Data* and *Send To Tool Manager* selections, when used, to fetch all the data that are not selected.

For further details on drill-through, see Chapter 18, "Selection and Drill-Through."

## The InterTool Menu

The InterTool menu has one option, as shown Figure 6-17.

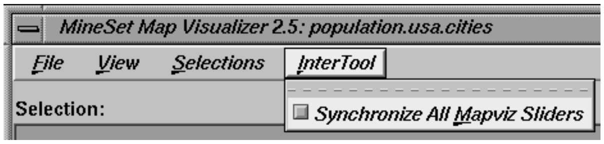

MineSet Map Visualizer 2.5: population.usa.cities
File
View
Selections
InterTool
Selection:
Synchronize All Mapviz Sliders

**Figure 6-17** Map Visualizer's InterTool Pulldown Menu

Selecting *Synchronize All Mapviz Sliders* identifies this Map Visualizer window as one in a "synchronized sliders" cooperative: changing the current slider positions in one Map Visualizer window causes/produces the same change in all others currently open. Click this option again to deselect it. This menu option must be selected in every Mapviz main window that is to be part of the synchronization.

Note that currently only the sliders' physical positions are synchronized, not the underlying meanings of those positions. For example, synchronizing *population.usa.mapviz* (with dates ranging from 1770 to 1990) and *population.canada.mapviz* (with dates ranging from 1871 to 1991) probably is not useful, since the slider physical midpoint position represents 1880 in the United States and 1931 in Canada. Generally, synchronization is useful only when the sliders of each dataset represent the same range of independent variables.

## The Help Menu

The Help menu is the same for all visualization tools; see "The Help Menu" in Chapter 5.

## Null Handling in the Map Visualizer

Nulls represent unknown data (see Appendix J, “Nulls in MineSet”).

In the Map Visualizer, nulls can occur when any of the following is true:

- The database or data file contains a null.
- The Tool Manager is used to make an array based on bins and no data falls into a specific bin. For example, if there is no data for the 30-40-year-old population, that bin is null.
- The Tool Manager is used to make an array and the null enum option is specified. In this case, an extra array element is created to represent the aggregation of all the values for which the bin value is null. The Tool Manager assigns the question mark (?) character to this extra bin. To view the values of this bin, move the corresponding slider to its left-most position. If there are no data for that null bin, the values associated with it are null as well, and the Map Visualizer represents the corresponding graphical object(s) as a “null object.”
- Expressions and aggregations of nulls can generate nulls (see Appendix J, “Nulls in MineSet”).
- The Map Visualizer uses special representations when a null value is mapped to a visual attribute. A null height results in a dark grey object with zero height; a null color results in an object with appropriate height (as defined by the value mapped to height), but with a dark gray color (see Figure 6-18).

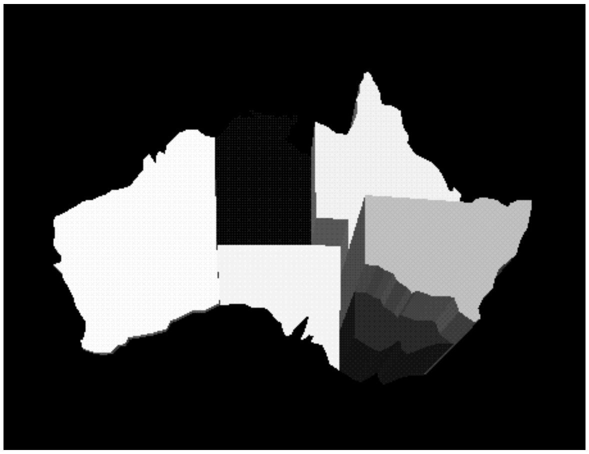


**Figure 6-18** Representation of a Null Value Mapped to Height (Top Middle Object) and to Color (Bottom Right Object)

When selecting an object with a null value, a question mark (?) is shown in the selection field.

## Sample Configuration and Data Files

The provided sample configuration and data files demonstrate the Map Visualizer's features and capabilities. The *.data* and *.mapviz* files are in the directory */usr/lib/MineSet/mapviz/examples*; the *.gfx* and *.hierarchy* files are in the directory */usr/lib/MineSet/mapviz/gfx_files*.

- *blocks.mapviz*, *blocks.data*, *blocks.gfx,* and *blocks.hierarchy*
  This simple example shows four adjacent blocks. The height and color of each block varies based on the underlying data in *blocks.data*. You can drill up using the middle mouse button (see the "Select Mode" section) to see the upper pair and the lower pair of blocks aggregate; then drill up again to see these upper and lower blocks aggregate into a single block. You can drill down using the right mouse button to see the objects of finer granularity reappear.

- *population.australia.mapviz*, *population.australia.data*, *australia.states.gfx,* and *australia.states.hierarchy*  
  The data file contains one row for each Australian state and territory. Each row contains three tab-separated items: a keyword name for the state or territory, the population value, and the size of the territory.

  This sample graphically displays the 1991 population and population density of the Australian states and territories. Heights of the graphical objects represent the relative population; color represents the relative population density. A legend at the bottom of the display describes the color range and the associated values.

- *population.canada.mapviz*, *population.canada.data*, *canada.provinces.gfx,* and *canada.provinces.hierarchy*  
  The data file contains one row for each Canadian province and territory. In this example, each row contains 13 blank-separated values (one for each decade between 1871 and 1991).

  This sample graphically displays the population and population density of the Canadian provinces and territories from 1871 to 1991, in 10-year increments. The animation control panel lets you dynamically view the datasets across a range of time. Animation operation is explained in "Sliders Controlling Independent Dimensions" on page 197.

- *population.europe.mapviz*, *population.europe.data*, *europe.countries.hierarchy,* and *europe.countries.gfx*  
  When graphically displayed, this shows the 1992 population and population density of countries in Western and Central Europe.

- *population.usa.mapviz*, *population.usa.data*, *usa.sates.gfx,* and *usa.sates.hierarchy*  
  When graphically displayed, this shows the population and population density of the United States from 1770 to 1990. The animation controls let you dynamically view population and density changes across time.

- *population.usa.cities.mapviz*, *population.usa.cities.data*, *usa.sates.gfx*, *usa.sates.hierarchy,* and *usa.cities.gfx* and *usa.cities.hierarchy*  
  The *usa.sates.gfx* file specifies the United States, which is displayed as a background. The *usa.cities.gfx* file specifies the location of the cities on this background. The *.data* file specifies the population of each city.

  This sample graphically displays the population of the 48 largest U.S. cities from 1950 to 1990. No data has been mapped to the colors. The animation controls let you dynamically view changes across time.

- *perhouse.perage.mapviz*, *perhouse.perage.data*, *usa.sates.gfx*, and *usa.sates.hierarchy*
  This sample graphically displays consumer household spending data from July-August 1988 to May-June 1991. Color is mapped to the gender of the spending household member; height represents the average dollar amount spent per household for a given time period and age group. This data has two independent dimensions: time and age. The highest spending is indicated in the summary window (see "The Summary Window" on page 199) by the areas with the greatest color density, namely "May-June 1989 (Age: 30-39)" and "May-June 1990 (Age: 30-39)."

- *telecom.mapviz*, *telecom.data*, *usa.cities.lines.gfx*, *usa.cities.lines.hierarchy*, *usa.sates.gfx,* and *usa.sates.hierarchy*
  This sample graphically displays a flat map with arched lines on it. These lines connect two endpoints. The lines can have variable width and color. In this example, the widths and colors are random; however, they could relate to the volume and duration of the connections between the endpoints.

- *fasta.m.data*, *fasta.m.mapviz*, *fasta.m.gfx,* and *fasta.m.hierarchy*

  The data file for this example contains the partial results of a full biological sequence comparison between two complete genomes (courtesy of Dr. Tom Flores, European Bioinformatics Institute). When graphically displayed, scientists can quickly identify and locate the regions of similarity between the two genomes. The ability to display such large amounts of information in a visual data exploration method such as this could be extended to include much more information about the individual genomes. Scientists could explore this data more easily and thereby perhaps better understand the function and purpose of the similar genetic sequences.

  In this example, the "map" is the circular-shaped genome of a biological organism called *Mycoplasma genitalium* (MG). The MG genome is divided into 500 equal segments, each representing a 1000-nucleotide sequence in the genome. The slider selects one of the segments of the second genome, called *Haemophilus influenzae* (HI), for cross-comparison between the two genomes. The Summary Window in the Animation Control Panel indicates which segments show the greatest similarities, and you can move the slider to examine those particular segments of interest. The bar heights and colors on the "map" therefore indicate the relative similarity of each MG segment to each HI segment, where higher bars correspond to greater measures of similarity. This similarity is measured by the "Reciprocal Evalues," which ranges from 0.0 to 1.0.

*Chapter 7*

# Using the Scatter Visualizer

This chapter discusses the features and capabilities of the Scatter Visualizer. It provides an overview of this database visualization tool, then explains the Scatter Visualizer's functionality when working with the

- main window
- external controls
- pulldown menus

Finally, it lists and describes the sample files provided for this tool.

## Overview of Scatter Visualizer

The Scatter Visualizer lets you visually analyze relationships among several variables (see Figure 7-1), either statically or by animation. It is particularly useful for seeing individual data points when you do not have a large number of records. If your dataset has a very large number of records consider using the Splat Visualizer. Analysis in the Scatter Visualizer is done using

- a three-dimensional landscape
- an animation control panel that includes a two-dimensional slider
- graphical objects, called *entities*, that can be animated in the three-dimensional landscape

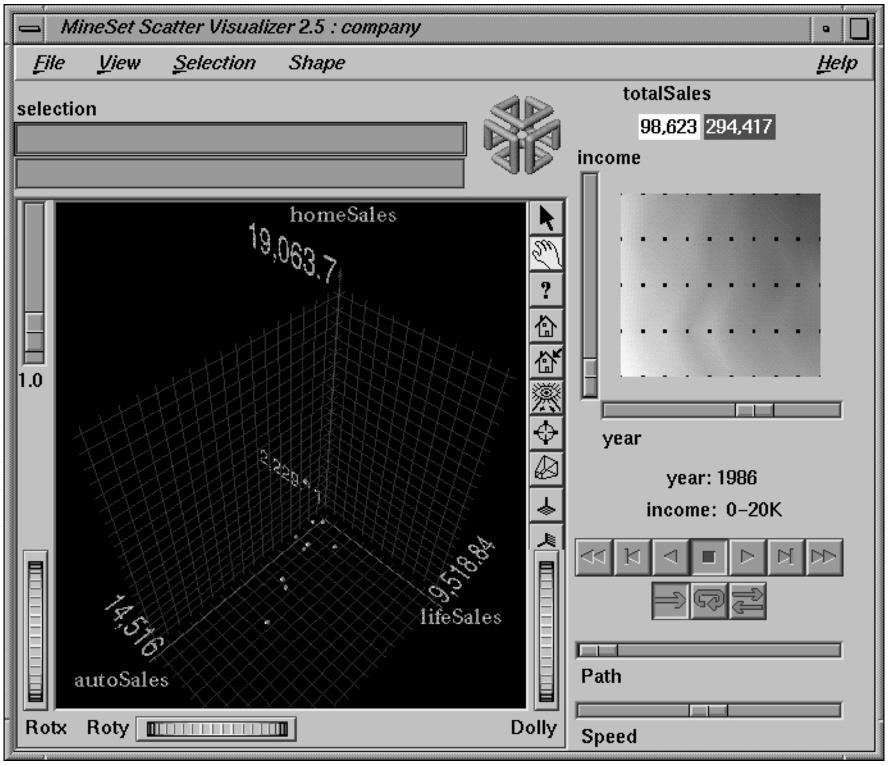


**Figure 7-1** Sample Scatter Visualizer Screen

The Scatter Visualizer lets you visualize your data by mapping each record, or row, in the dataset to an entity in the three-dimensional landscape. Variables in the data can be mapped to the sizes, colors, and positions of the entities. Also, you can map one or two numeric variables to the sliders in the animation control panel. If the variables mapped to sizes, colors, or positions of the entities depend on the variables mapped to sliders, the sliders can be used to drive an animation. For example, the data might represent the sales of several companies over time. If the time variable is mapped to a slider and the sales variable is mapped to size, then the entities grow or shrink as the time slider is animated.

After you create a visualization of your data, the Scatter Visualizer lets you analyze the data in various ways. The animation control panel lets you trace animation paths in one or two dimensions. By playing back the path you created, you can watch the size, color, and motion of the entities for trends or anomalies. In the three-dimensional landscape, you can orient the display to emphasize particular dimensions or a point of view. The Scatter Visualizer lets you scale the values of variables to give them greater emphasis. Also, you can filter the display to show only those entities meeting certain criteria.

## File Requirements

The Scatter Visualizer requires the following files:

- A data file, consisting of rows of tab-separated fields. This file is easily created using the Tool Manager (see Chapter 3). If you are generating this file yourself, see Appendix D, “Creating Data and Configuration Files for the Scatter Visualizer” for the required file format.

  You can generate data files by extracting data from a source (such as a database) and formatting it specifically for use by the Scatter Visualizer. Data files have user-defined extensions (the sample files provided with the Scatter Visualizer have a *.data* extension).

- A configuration file, describing the format of the input data and how it is to be displayed. The Tool Manager can create this file (see Chapter 3), or you can use an editor (such as jot, vi, or Emacs) to produce this file yourself (see Appendix D, “Creating Data and Configuration Files for the Scatter Visualizer”).

  Configuration files must have a *.scatterviz* extension. When starting the Scatter Visualizer, or when opening a file, you must specify the configuration file, not the data file.

### Options for Invoking the Scatter Visualizer

There are a two options that affect how this tool is invoked:

- **`-warnexecute`** indicates that if you attempt to execute a command specified in an execute statement, a warning is displayed and you are given the option to execute the command or not. This is intended for an insecure environment, such as files obtained from the Web, and is used automatically when commands are executed via mtr files.

  You can enable this option permanently by adding the line

  ```
  *minesetWarnExecute:TRUE
  ```

  to your *.Xdefaults* file, or by setting the environment variable

  ```
  MINESET_WARN_EXECUTE
  ```

- **`-quiet`** eliminates the dialogs that popup to indicate progress. You can enable this option permanently by adding the line

  ```
  *minesetQuiet:TRUE
  ```

  to your *.Xdefaults* file.

## Starting the Scatter Visualizer

There are five ways to start the Scatter Visualizer:

- Use the Tool Manager to configure and start the Scatter Visualizer. (See Chapter 3 for details on most of the Tool Manager's functionality, which is common to all MineSet tools; see "Configuring the Scatter Visualizer Using the Tool Manager" on page 220 for details about using the Tool Manager in conjunction with the Scatter Visualizer.)
- Double-click the Scatter Visualizer icon, which is in the MineSet page of the icon catalog. The icon is labeled *scatterviz*. Since no configuration file is specified, the start-up screen requires you to select one by using File > Open.

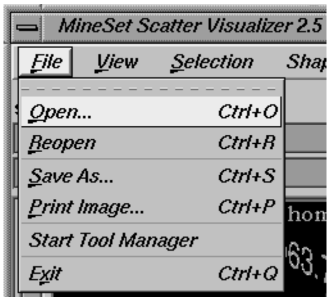


**Figure 7-2** Scatter Visualizer Start-Up File Pulldown Menu Selected

Starting the Scatter Visualizer without specifying a configuration file causes the main window to show the copyright notice and license agreement for this tool. Only the File and Help pulldown menus can be used. For the main window to be fully functional, open a configuration file by selecting File > Open.

- If you know which configuration file you want to use, double-click the icon for that configuration file. This starts the Scatter Visualizer and automatically loads the configuration file you specified. This works only if the configuration filename ends in *.scatterviz* (which is always the case for configuration files created for the Scatter Visualizer using the Tool Manager).
- Drag the configuration file icon onto the Scatter Visualizer icon. This starts the Scatter Visualizer and automatically loads the configuration file you specified.
- Start the Scatter Visualizer from the UNIX shell command line by entering this command at the prompt:

  ```
  scatterviz [ configFile ]
  ```

  *configFile* is optional and specifies the name of the configuration file to use. If you don’t specify a configuration file, you must use File > Open to specify one (see Figure 7-2).

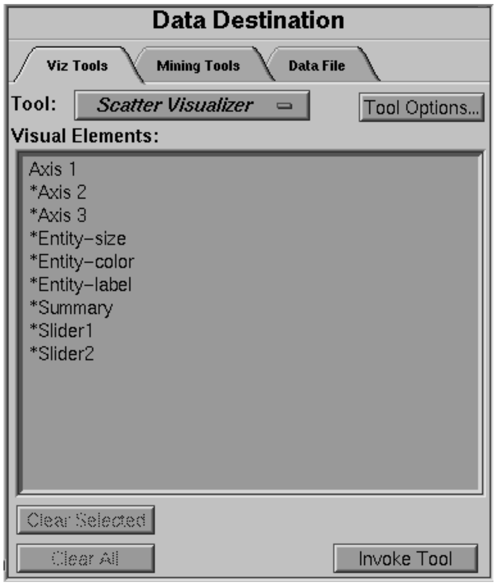
## Configuring the Scatter Visualizer Using the Tool Manager

This section describes how the Scatter Visualizer can be configured using the Tool Manager. Although the Tool Manager greatly simplifies the task of configuring the Scatter Visualizer, you can construct a configuration file manually for this tool using a text editor (see Appendix D, "Creating Data and Configuration Files for the Scatter Visualizer").

The steps required to connect to a data source are described in Chapter 3.

### Selecting the Scatter Visualizer Tool

Select the *Viz Tools* tab in the Data Destination panel of the Tool Manager's main screen (Figure 7-3). From the popup list of tools, select *Scatter Visualizer.* The mapping requirements for the Scatter Visualizer are displayed in the window on the right side of this panel. Items in the Visual Elements list that are preceded by an asterisk are optional.



Tool: Scatter Visualizer

Visual Elements:

Axis 1
*Axis 2
*Axis 3
*Entity–size
*Entity–color
*Entity–label
*Summary
*Slider1
*Slider2

**Figure 7-3** Data Destination Panel With Scatter Visualizer Selected

- *Axis 1*, **Axis 2*, **Axis 3* let you assign to the axes in the Scatter Visualizer's main window the data you want represented. Assigning data to Axis1 is required. However, this alone does not produce a useful display. By assigning data to Axis 2, you can create an XY chart. Assigning data to all three axes produces a 3-D chart.
- **Entity-size*, **Entity-color*, **Entity-label* let you assign size, color, and label to the entities appearing in the Scatter Visualizer's main window.
- **Summary* is the value mapped to the summary column, if you have a slider. It determines the color of the slider's background.
- **Slider1* and **Slider2* let you map columns directly to one or two animation Sliders (see "Slider Creation for Scatterviz," below).

### Mapping Requirements to Columns

You can map requirements to columns by selecting a column name in the Current Columns window of the Table Processing panel, then selecting a category in the Visual Elements window.

### Undoing Mappings

To undo a specific mapping, select that mapping in the Visual Elements window, then click the *Clear Selected* button. To undo all mappings, click the *Clear All* button.

### Slider Creation for Scatterviz

Sliders can be created manually or automatically. The following subsections describe these methods.

### Manual Slider Creation

Tool Manager generates sliders whenever there is an array column present in the current table. The sliders correspond to the indices of the array columns. If the column has one index (one-dimensional array), only one slider is created, but if the column has two indices (two-dimensional array), both an X and a Y slider are created. The current slider indices are indicated in the Tool Options dialog box from the Tool Manager. Array columns can be created using the "index by" menus in the Tool Manager aggregation panel (see "Aggregation" in Chapter 3).

Note that for a slider to be created, all array columns in the current table must have the same indices. If array columns with differing indices exist in the current table, no sliders are created.

### Automatic Slider Creation

If no arrayed columns are in the current table, Tool Manager can automatically generate sliders by use of the Slider1 and Slider2 mappings. Sliders are created through a combination of automatic binning and aggregation. These automatic operations occur after clicking *Invoke Tool* in the Data Destination Panel. The operations do not affect the current history operations of Tool Manager, but they do appear in the configuration files for the tool.

Columns mapped to Slider1 and Slider2 eventually form the indices for the sliders. These columns must be either numeric (int, float, double) or binned. If a column mapped to a slider is already binned, no automatic binning is needed for this column, and this column is used as an index for a slider. However, if the column is not binned, a binned column is created using the automatic binning options in the Tool Options dialog box.

The three methods of binning are:

- Selecting All Distinct Values creates a bin for every unique value of the column.
- Specify the number of bins you want to create. The thresholds for the bins are determined using the Uniform Range approach.
- Selecting Automatic automatically determines the number of bins to create and determines the bin thresholds using the Uniform Range approach.

(See "The Bin Columns Button" in Chapter 3 for more information about binning.) The column used in forming the automatic bins is deleted from the current table.

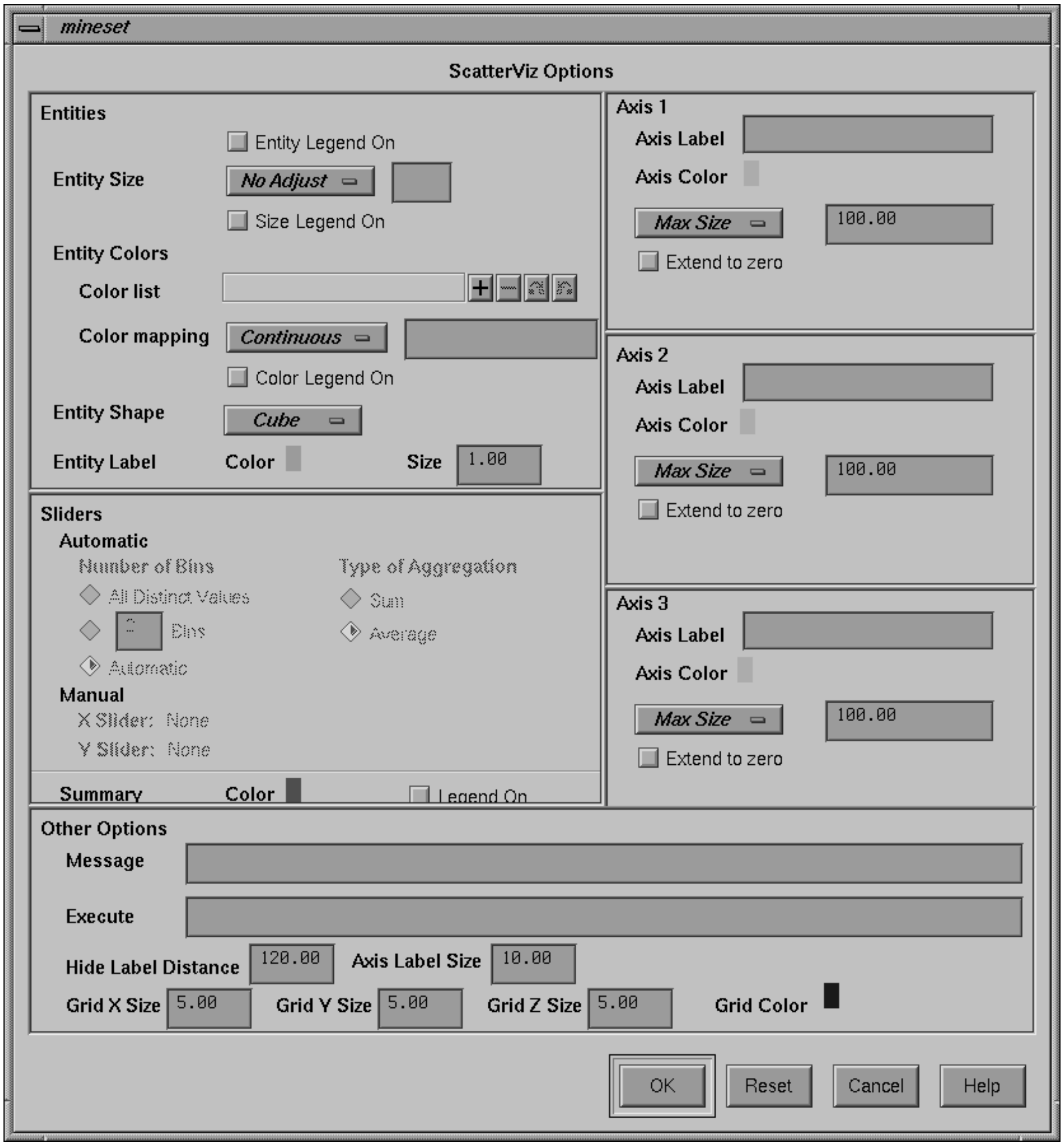
The binned columns now form the indices of array columns. Note that if you want to create only one slider, the index must be mapped to Slider1. Attempting to create only one slider with a mapping to Slider2 is not allowed and generates a Tool Manager error. Also, a column mapped to a slider cannot be mapped to any other mapping, since it is removed during the aggregation process.

Once the slider indices are formed, the arrayed columns are created. This is done using automatic aggregation. Any numeric columns mapped to Axis 1, Axis 2, Axis 3, Entity-size, Entity-color, Entity-label, or Summary are aggregated using the automatic aggregation options in the Tool Options dialog box. You can either specify aggregating by Sum or by Average. The binned columns created from the slider mappings form the indices for the aggregation, and any remaining columns in the table are Group-By columns. (See “Aggregation” in Chapter 3 for a description of the aggregation process.) Be sure to remove any columns you do not wish to use in the grouping process. If you need different types of aggregates for different mappings, you must aggregate manually.

The aggregation step automatically forms the arrayed columns used for sliders. These arrayed columns form the new tool mappings. For example, if the column “mpg” were mapped to Axis 1, a new column “avg_mpg[]” is formed and remapped to Axis 1. The progress of the automatic slider generation is displayed in the Tool Manager status window.

## Specifying Tool Options

Clicking the *Tool Options* button causes a new dialog box to be displayed (Figure 7-4). This lets you change some of the Scatter Visualizer options from their default values.



mineset

ScatterViz Options

Entities

□ Entity Legend On

Entity Size: No Adjust

□ Size Legend On

Entity Colors

Color list: + −

Color mapping: Continuous

□ Color Legend On

Entity Shape: Cube

Entity Label: Color ▨ Size 1.00

Sliders

Automatic

Number of Bins: ◇ All Distinct Values ◇ 2 Bins ◆ Automatic

Type of Aggregation: ◇ Sum ◆ Average

Manual

X Slider: None

Y Slider: None

Summary: Color ■ □ Legend On

Axis 1

Axis Label

Axis Color ▨

Max Size 100.00

□ Extend to zero

Axis 2

Axis Label

Axis Color ▨

Max Size 100.00

□ Extend to zero

Axis 3

Axis Label

Axis Color ▨

Max Size 100.00

□ Extend to zero

Other Options

Message

Execute

Hide Label Distance 120.00 Axis Label Size 10.00

Grid X Size 5.00 Grid Y Size 5.00 Grid Z Size 5.00 Grid Color ■

**Figure 7-4** Scatter Visualizer’s Options Dialog Box

The Scatter Visualizer's Options dialog box has four basic options blocks:

- Entities
- Sliders
- Axes
- Other

### Entity Options

This option block lets you specify a number of characteristics for the entities that the Scatter Visualizer then graphically displays.

- *Entity Legend On*—lets you determine whether the entity legend is displayed or hidden.
- *Entity Size*—lets you scale the entity to a max size, a scale size, or a default (no adjustment). You also can specify whether the legend for entity size is displayed or hidden.
- *Entity Colors*—lets you control the colors in which entities are displayed. You can
  - specify the list of colors to use
  - specify the kind of mapping
  - map the list of colors to a list of values
  - specify whether the legend for color is displayed or hidden
  - map colors to entities
- *Entity Shape*—lets you choose a visual representation for the entities: cubes, bars, or diamonds.

To use these Colors options, you must have mapped a column to the *Entity-color requirement of the Data Destination panel. See "Choosing Colors" and "Using the Color Browser" in Chapter 3 for a more detailed explanation of how to choose and change colors.

*Color list to use* lets you specify the color list using the + button next to the color list label. This brings up a color editor that lets you specify a color to be added to the list.

*Color mapping* let you specify whether the color change that is shown in the graphic display is *Continuous* or *Discrete*. If you choose *Continuous*, the color values shift gradually between the colors entered in the *Color list to use* field as a function of the values that are mapped to those colors in the *Color mapping* field.

The field to the right of the popup button lets you enter specific values for mapping the colors. If you do not specify any mapping values, the range of values in the color variable is used.

**Example 7-1**

If you

- used the Color Browser to apply red and green to bars
- selected *Continuous* for the *Kind of mapping*
- entered the values `0 100`

then the display shows all entities with values less than or equal to 0 as completely red, those as greater than or equal to 100 as completely green, and those between 0 and 100 as shadings from red to green.

**Example 7-2**

If you

- used the Color Browser to apply red and green to entities
- selected *Discrete* for the *Kind of mapping*
- entered the values `0 50`

then the display shows all entities with values of less than 50 in red, and all those with values greater than or equal to 50 in green.

- *Entity Label Color* lets you modify a label color by clicking on it. This causes the Color Choose dialog box to appear, which lets you implement your color changes.
- *Entity Label Size* controls the size of the entity labels. A smaller number decreases the size, a larger one increases it.

### Summary Options

Summary options let you specify what color to use for the Summary window. You can also specify whether the summary legend, which indicates what the values are, is displayed or hidden.

If you have an array of values, you can specify an X or Y slider. The popup buttons next to these options provide a list of available keys, and let you specify which to use as sliders.

### Slider Options

The Slider options control how the slider mappings are interpreted. For details see “Slider Creation for Scatterviz” on page 221.

### Axis Options

The Axis options let you specify the following, for each axis:

- A label. (If you leave this box blank, the Scatter Visualizer defaults to using the column names for each axis.)
- A color
- A size type for each axis. (This can be *Max Size*, *Scale Size*, or *No Adjustment*.)
  - *Max Size* lets you specify that an axis is scaled independently to a specified size. If one axis has a Max Size that is twice as large as the other, it will be twice as long, regardless of the data values. This option is most useful when comparing axes that are in different units (for example, comparing income to age). This option has no effect on non-numeric data.
  - *Scale Size* lets you specify that the axis is scaled based on its maximum value. If two axes have the same Scale Size, but one has a maximum that is twice the value of the other, the former will be twice as long as the latter. This option is useful for comparing axes with the same units (for example, income vs. expenses). This option does affect the size of non-numeric axes.
  - *No Adjust* is equivalent to a *Scale Size* of 1.0.
- A size value
- Whether the axis should be extended to include the value 0.

### Other Options

The Other Options, at the bottom of the dialog box, include the following fields:

- *Message* lets you specify the message displayed when an entity is selected. For a listing and description of format types that can be entered in this field, see the "Message Statement" section in Appendix D, "Creating Data and Configuration Files for the Scatter Visualizer"
- *Execute* lets you type in a UNIX command that is executed when double-clicking on an entity. The format is similar to the message statement. If no execute statement appears, double-clicking has no effect. For a detailed description of the Execute field, see "Execute Statement" in Appendix D.
- *Hide Label Distance* controls the distance at which entity labels become invisible. Smaller distances might improve performance, but the labels disappear more quickly. The higher the number, the greater the distance at which labels are hidden.
- *Axis Label Size* controls the size of the axis labels. A smaller number decreases the size, a larger one increases it.
- *Grid (X, Y, Z) Size* lets you specify the spacing between grid lines for the respective axis. A smaller number decreases the size, a larger one increases it.
- *Grid Color* lets you modify a grid color by clicking on it. This causes the Color Chooser dialog box to appear, which lets you implement your color changes.

### Resetting the Tool Options

If you want to reset the values of all options to their default values, click the *Reset Options* button.

### Saving the New Tool Options

Once you have finished making changes to the Tool Options dialog box, click *OK* to return to the Tool Manager's main screen.

## Invoking the Scatter Visualizer

To see Scatter Visualizer graphically represent your data, click the *Invoke Tool* button at the bottom of the Data Destination panel.

## Saving the Scatter Visualizer Settings

When you press *Invoke Tool,* the Tool Manager stores information for the Scatter Visualizer in three files, all sharing the same prefix:

- *<prefix>.scatterviz.data* contains data.
- *<prefix>.scatterviz.schema* describes the data file.
- *<prefix>.scatterviz* contains information needed by the Scatter Visualizer.

To save the entire session along with the current tool options, use one of these menu options from the File menu:

- *Save Current Session...* where the default prefix is based on the data source
- *Save Current Session As...* to specify your own prefix

The saved file is *<prefix>.mineset,* and contains all the information needed to return MineSet to its current state.

## Null Handling in the Scatter Visualizer

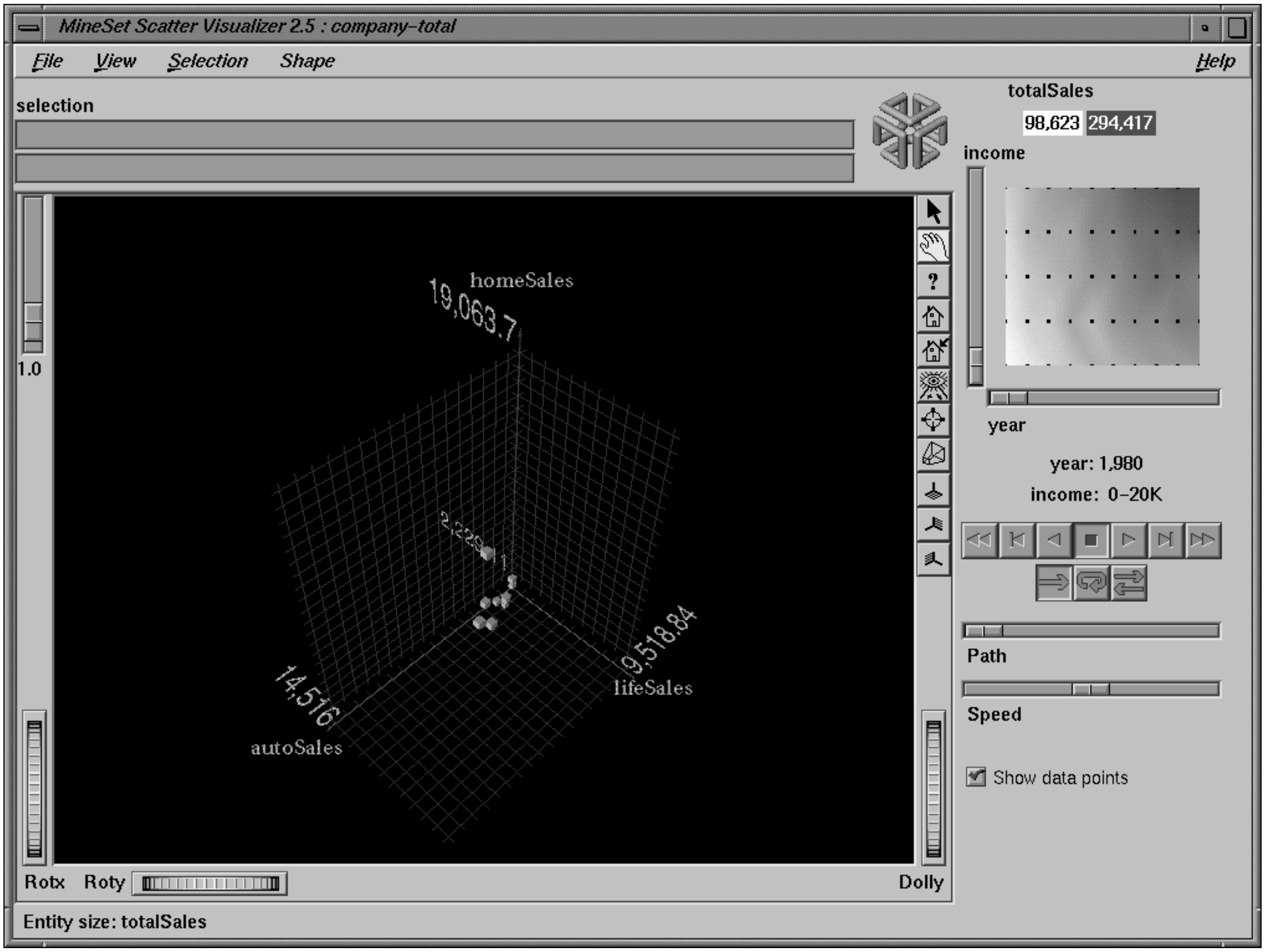
The Scatter Visualizer uses special representations when fields with unknown data values, or nulls, are mapped to visual attributes. (For a discussion of null values, see Appendix J, “Nulls in MineSet.”) When a null value is mapped to an entity’s size, the entity is drawn as the outline of a cube. When a null value is mapped to an entity’s color, it is drawn in dark grey. When a null value is displayed in the Selection Window or “Pointer is Over” area, it is shown as a question mark (?). (The Selection Window and “Pointer is Over” areas are discussed in the “Select Mode” section.)

If a null value is mapped to the *x*, *y*, or *z* position of an entity, the result depends on the Show Entities with Null Positions option under the View Menu (see “The View Menu” on page 241). If the option is set, the entity is shown just below the range of the corresponding axis. If the option is not set, the entity is not shown.

## Working in the Scatter Visualizer's Main Window

If you started the Scatter Visualizer without specifying a configuration file, the main window shows the copyright notice and license agreement for the Scatter Visualizer. Only the File and Help pulldown menus can be used. For the main window to show all menus and controls, open a configuration file. Use File > Open (Figure 7-2) to see a list of configuration files.

When a valid configuration file has been selected, the 3D landscape it specifies is visible. For example, selecting *company-total.scatterviz* gives results as shown in Figure 7-5.



Entity size: totalSales

**Figure 7-5** Initial View When Specifying company.scatterviz

This shows the sales of life insurance, auto insurance, and home insurance with respect to income brackets over time.

## Viewing Modes

The two modes of viewing are *grasp* and *select*. To toggle between these modes, press the Esc key or click the appropriate cursor button adjacent to the top-right of the viewing area.

### Grasp Mode

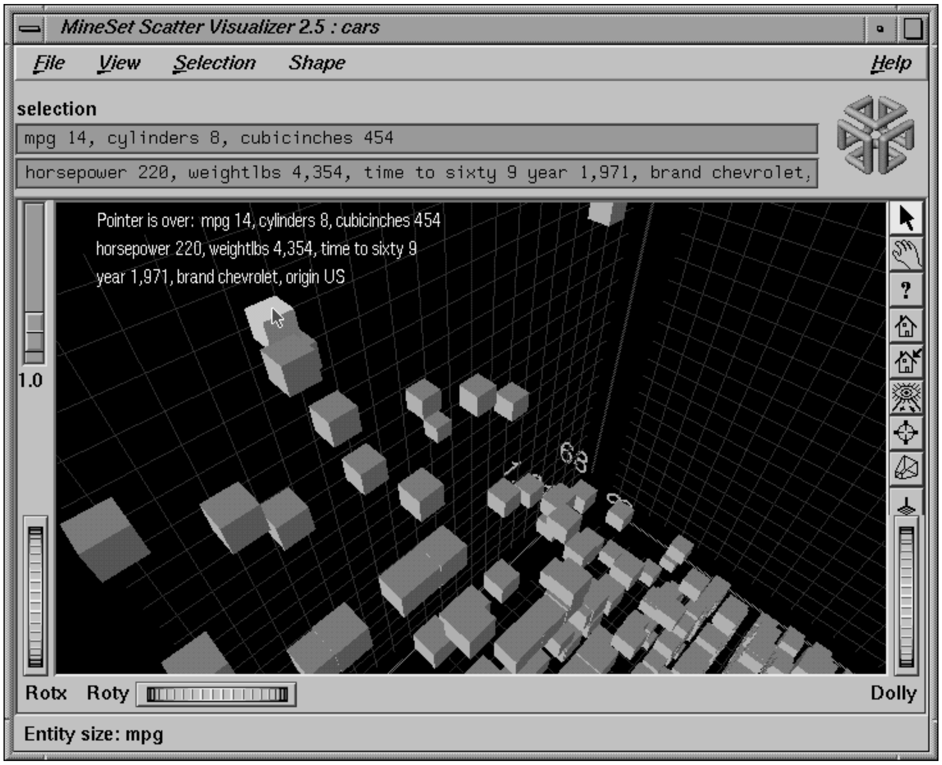
In *grasp* mode, the cursor appears as a hand. This mode supports panning, rotating, and scaling the scene's size in the main window.

- To pan the display, press the middle mouse button and drag it in the direction you want the display panned.
- To rotate the display, press the left mouse button and move the mouse in the direction you want to rotate. (Also see the thumbwheel controls *Rotx* and *Roty*, described in "Thumbwheels" in Chapter 6.)
- To move the viewpoint forward, press the left and middle mouse buttons simultaneously and move the mouse downwards. To move the viewpoint backward, press the left and middle mouse buttons simultaneously and move the mouse upwards. This is equivalent to the functions provided by the Dolly thumbwheel.

### Select Mode

In *select* mode, you can highlight an object by positioning the cursor over that object. Information about that object then appears at the top of the view area, under the *Pointer is over:* label (Figure 7-6). This information remains visible in the window only as long as the pointer cursor remains over the object. Position the pointer cursor over an object and click the left mouse button; the same information appears in the Selection Window, above the main window. A white box appears around the entity, indicating it has been selected, and a table viewer shows your current selection. Select several entities by holding down the Shift key while clicking the left mouse button. The most recent selection is shown under the Selection label at the top of the scene. All current selections are shown in the Record Viewer. You can now drill-through on your selection (see "The Selection Menu" on page 279 for the different drill-though options.)

This Selection information remains visible until another object is selected, or you click the black background. Using the mouse, you can cut and paste this selection information into other applications, such as reports or databases.



mpg 14, cylinders 8, cubicinches 454

horsepower 220, weightlbs 4,354, time to sixty 9 year 1,971, brand chevrolet,

Pointer is over: mpg 14, cylinders 8, cubicinches 454
horsepower 220, weightlbs 4,354, time to sixty 9
year 1,971, brand chevrolet, origin US

Entity size: mpg

**Figure 7-6** Displayed Information When Cursor is Over a Selected Entity

If an execute statement was specified using Tool Manager or the configuration file, then double clicking on an object executes the appropriate command. If the `-warnexecute` option was specified when invoking the Scatter Visualizer, a warning is given first.

**Note:** Users familiar with Open Inventor can configure the Scatter Visualizer so that the right mouse button brings up the standard Inventor Menu. This provides additional functions, such as stereo viewing and spin animation. These functions are provided by the Open Inventor library. To enable the Open Inventor Menu, add the line
```
*minesetInventorMenu:TRUE
```
to your *.Xdefaults* file.

## External Controls

Several external controls surround the main window, including buttons and thumbwheels. These controls are substantially the same for most MineSet visualization tools (see the descriptions “Buttons” in Chapter 6, and “Thumbwheels” in Chapter 6).

## The Animation Control Panel

The animation control panel, which appears to the right of the main window, consists of a summary window, with up to two adjacent sliders, an information field, animation buttons, and animation sliders.

### Sliders Controlling Independent Dimensions

The number of sliders appearing adjacent to the summary window is dependent on the dataset displayed in the Scatter Visualizer’s main window. Datasets can have two, one, or no independent dimensions.

#### Datasets With Two Independent Dimensions

If the dataset has two dimensions of independently varying data (such as *company.scatterviz*), the controls to the right of the main graphics window become visible (see Figure 7-7).

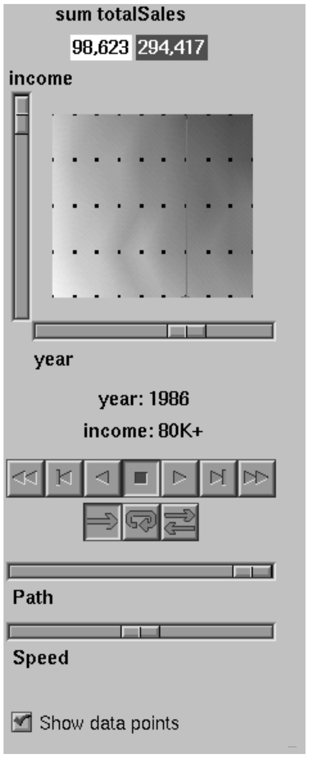


**Figure 7-7** Animation Control Panel With Summary Window and Both Slider Controls

To the right of the main window are the summary window and slider controls. The summary window has a horizontal slider below it for selecting data points of the first independent dimension, and a vertical slider to the left for selecting data points of the second independent dimension. The horizontal slider's dimension is identified by a label below it. The vertical slider's dimension is identified by a label above it.

### Datasets With One Independent Dimension

For datasets with one independent dimension (such as *store-type.scatterviz*), only the slider below the summary window appears, and the summary window is compressed (see Figure 7-8). This slider’s dimension is identified by a label below it.

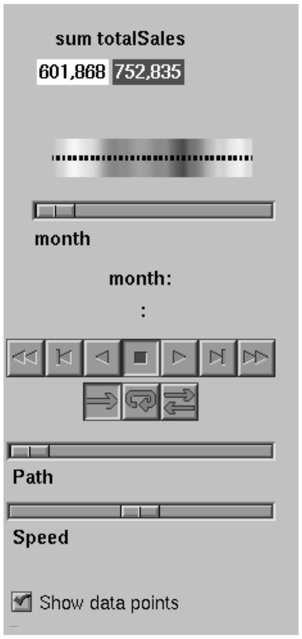
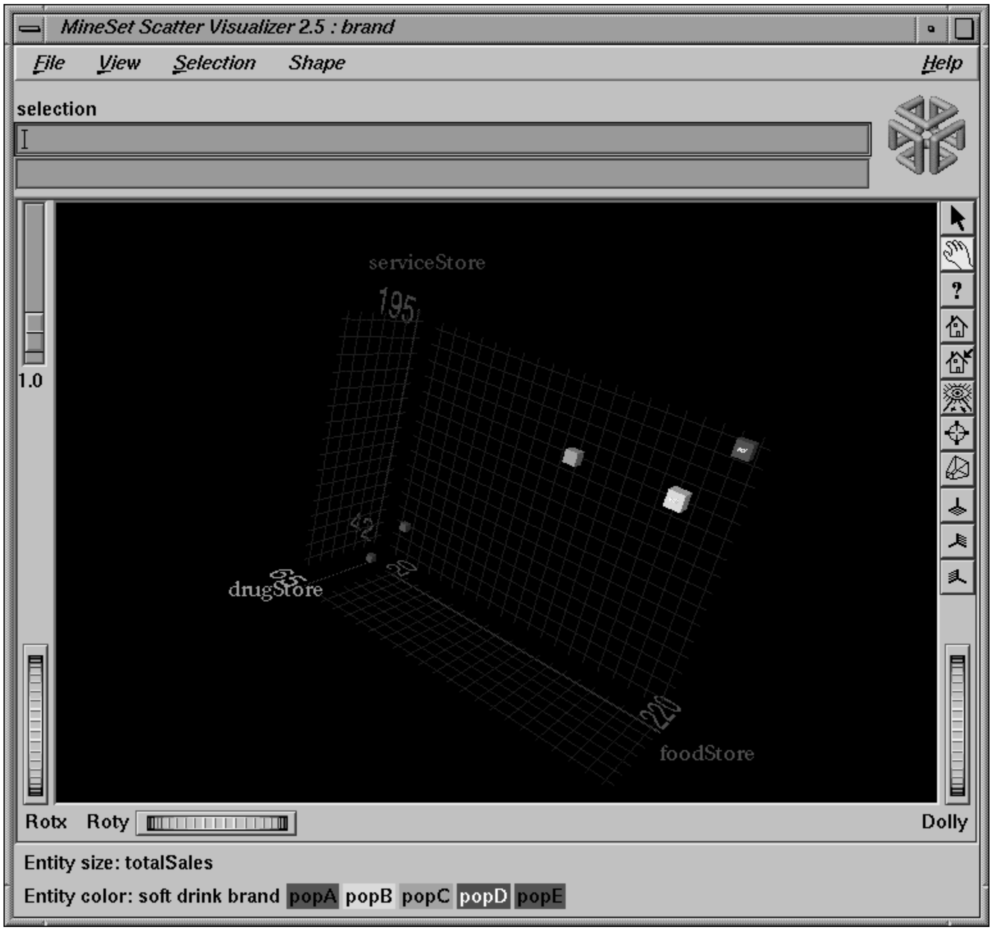


**Figure 7-8** Animation Control Panel With Summary Window and One Slider Control

### Datasets With No Independent Dimension

For datasets with no independent dimensions (such as *brand.scatterviz*), no slider control appears (see Figure 7-9).



Entity size: totalSales

Entity color: soft drink brand popA popB popC popD popE

**Figure 7-9** Scatter Visualizer With No Independent Dimension or Animation Control Panel

## The Summary Window

The summary window provides a 2D representation of the aggregation of values that the main window displays in 3D. The whiter the areas of the summary window, the lower the total values represented by the entities in the main window. The greater the color density in areas of the summary window, the higher the total of those values. The density of these colors in the summary window provides a summary of the data across the one or two independent dimensions in the dataset.

By default, the summary window also contains a set of black dots, evenly spaced across the one or two dimensions of data. These dots indicate the precise positions of the discrete datapoints. You can turn off these black dots using the View | Show Data Points menu option.

### Color Density Examples in the Summary Window

After opening the *company.scatterviz* file, for example, the 2D summary window shows a color range from white (on the left) to red (on the right). White corresponds to a low sales volume; red represents a higher aggregate sales volume. In this example, the greater the density of red, the higher the total sales of life, auto, and home insurance.

### Creating a Path in the Summary Window

If the dataset loaded into the Scatter Visualizer has at least one independent dimension, it is possible to view all or any part of that dataset via animation. This is done by first creating a path in the summary window (this path connects a sequence of data points), then activating the animation controls described in the next section.

The three ways to draw a path in the summary window are as follows:

- Define a starting point by clicking and holding down the left mouse button, then draw a path by dragging the cursor over the window. End the path by releasing the left mouse button.
- Define a starting point by clicking the left mouse button, then define an endpoint by moving the cursor to another part of the window and clicking the middle mouse button. A line appears between those two points. To add more line segments, continue with repeated middle mouse clicks.
- Define a starting point by clicking the left mouse button, then drag one of the independent dimension sliders, thus drawing a straight line along this dimension. If there are two sliders, use of the second slider causes a straight line to be drawn along the axis controlled by this second slider.

## Animation Buttons and Sliders

The seven VCR-like buttons and two sliders (Path and Speed) below the 2D summary window let you control the animation.

### Animation Buttons

Once a path is drawn in the summary window (see "Creating a Path in the Summary Window," above), you can use the VCR-like buttons to control animation along this path. The middle *Stop* button is highlighted in blue, indicating an initial state. Use the adjacent *Play Forward* button (to the right of *Stop*) or *Play Reverse* (to the left) to begin simple movement along the drawn path in a forward or reverse direction. (*Forward* and *Reverse* are defined by the sequence in which the path was drawn, not by the left-to-right or right-to-left movement.)

To stop and restart the animation, click the *Stop* button, then use the *Play Forward* or *Reverse* button again. Note that when you stop, the animation continues in the current direction until the position falls upon a discrete data point.

Adjacent to the *Play* buttons are the *Single-Step* buttons, as well as *Forward* and *Reverse*. Clicking on one of these buttons changes the current path position to the next discrete data point.

On the outside are the *Fast Forward* and *Fast Reverse* buttons. Clicking one of these buttons while in *Stop* state changes the path position to the end (for *Forward*) or to the beginning (for *Reverse*) of the path. Clicking a *Fast* button when in *Play* state increases the animation speed.

### Animation Flow

Below the Animation Buttons are the three Animation Flow buttons.

*Play-once* (default)**—**the animation moves either forward or in reverse until it reaches the end of the path, then stops.

*Loop***—**when the animation reaches the end of the path, it automatically resets to the beginning and starts over again.

*Swing***—**when the animation reaches the end of the path, it reverses direction and retraces its path to the other end; upon reaching that end, the animation reverses direction again, beginning the cycle again.

### Animation Sliders

While animation is stopped, you can move the Path slider to reset the position along the path. Note that when you use the Path slider, the cursor in the summary window moves across the drawn path, and the 1D sliders (below and to the left of the drawing area) move consistently with the cursor position. Then use the *Play* or *Reverse* button to restart the animation from the newly specified point. You can drag the Path slider to an arbitrary position between discrete data points; however, when you release the slider, the path position changes to the nearest discrete data point.

Use the Speed slider to adjust the speed of the animation along the path.

### Data Points and Interpolation

As animation proceeds, the variables mapped to size, color, and axes (positions) in the Scatter Visualizer change smoothly. However, the information displayed in the "Selection:" message box and the *Pointer is over:* field show only the data values of the nearest discrete data position; they do not show interpolated data values.

The animation is produced in the following manner: Assume you have data for 10 years, on a per-year basis (that is, 10 data values) and that these correspond to the size of one entity in the Scatter Visualizer. Assume further that the years are 1991 to 2000, the size for 1991 is 20, and the size for 1992 is 40. As you move the year slider from 1991 to 1992, the size changes by being uniformly interpolated between 20 and 40. For example, midway between 1991 and 1992, the size is 30. As you approach 1992, the size approaches 40. However, you cannot stop an animation between discrete data points, and you cannot drag the Path slider to a stationary position between discrete data points.

The data points in the summary window represent the slider positions corresponding to the actual data from the data file. For example, sizes 20 and 40 are representations of actual data, but size 30 is not. In this example, there would be data points in the summary window at the slider positions corresponding to each year.

Note that not all variables are required to vary with a slider. If there are two sliders, some variables can vary with only one of the sliders, while other variables vary with both.

## Pulldown Menus

Four pulldown menus let you access additional Scatter Visualizer functions. These are labeled File, View, Selections, and Help. If you start the Scatter Visualizer without specifying a configuration file, only the File and the Help menus are available.

### The File Menu

The File menu is the substantially the same for all visualization tools see "The File Menu" in Chapter 5.

### The View Menu

The View menu lets you control certain aspects of what is shown in the Scatter Visualizer window (Figure 7-10).

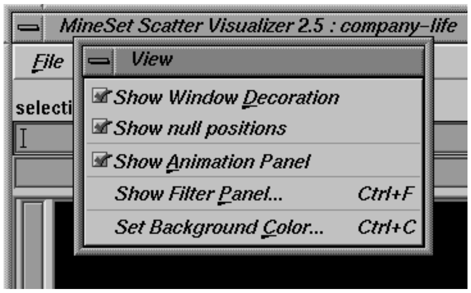
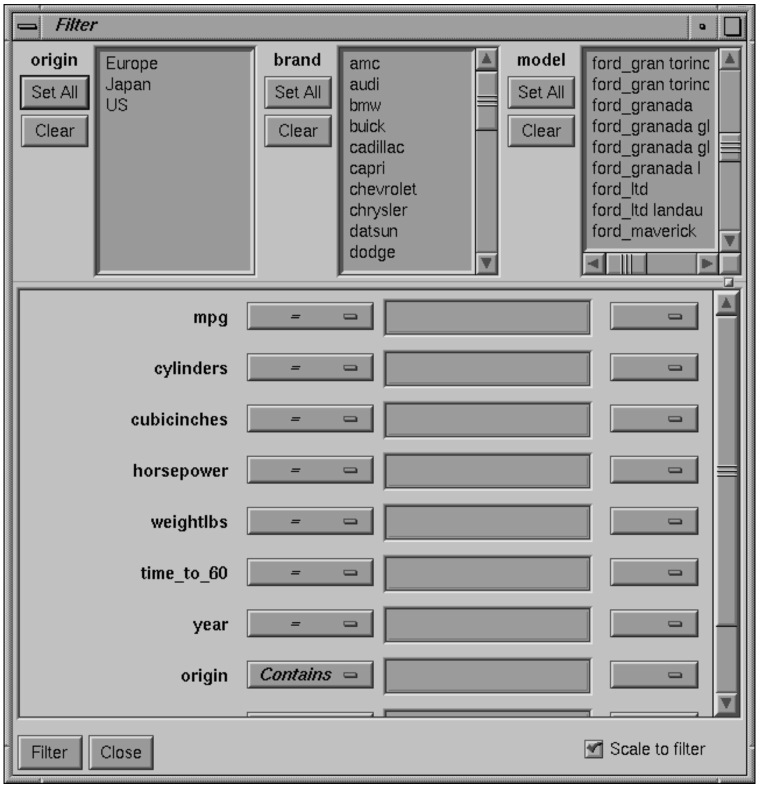

MineSet Scatter Visualizer 2.5 : company–life
File
selecti
View
☑ Show Window Decoration
☑ Show null positions
☑ Show Animation Panel
Show Filter Panel... Ctrl+F
Set Background Color... Ctrl+C

**Figure 7-10** Scatter Visualizer View Menu

- *Show Window Decoration* lets you hide or show the external controls around the main window.
- *Show null Positions* lets you hide or show entities that have null or unknown position values along one or more axes.
- *Show Animation Panel* lets you show or hide the animation control panel. This menu item is disabled for datasets with no independent dimension.

- *Show Filter Panel* lets brings up the Filter Panel. This panel (Figure 7-11) lets you reduce the number of entities displayed in the main viewing area, based on one or more criteria. You can use the filter panel to fine-tune the display, emphasize specific information, or simply shrink the amount of information displayed. The Set Landscape to Filter checkbox, which appears in the lower right of the filter panel, lets you specify whether the landscape in the main window covers the entire dataset or just the filtered data.
- *Set Background Color* brings up a color chooser to let you specify a new background color.



origin: Europe, Japan, US

brand: amc, audi, bmw, buick, cadillac, capri, chevrolet, chrysler, datsun, dodge

model: ford_gran torinc, ford_gran torinc, ford_granada, ford_granada gl, ford_granada gl, ford_granada l, ford_ltd, ford_ltd landau, ford_maverick

mpg =

cylinders =

cubicinches =

horsepower =

weightlbs =

time_to_60 =

year =

origin Contains

☑ Scale to filter

**Figure 7-11** Scatter Visualizer Filter Panel

The Filter panel has two panes. The top pane lets you filter based on string columns. To select all values of a column, click *Set All*. To clear the current selections, click *Clear*. To select a value, click it. To deselect a value, simply click it again.

The bottom pane lets you filter based on the values of both string and numeric columns.

To filter numeric values, enter the value, and select a relational operation (=, !=, >, <, >=, <=). To filter alphanumeric values, enter the string. You can use any of three types of string comparisons:

- Contains indicates that it contains the appropriate string. For example, "California" contains the strings "Cal" and "forn".
- Equals requires the strings to match exactly.
- Matches allows wildcards:

– An asterisk (*) represents any number of characters.

– A question mark (?) represents one character.

– Square braces ([ ]) enclose a list of characters to match.

For example, California matches Cal*, Cal?fornia, and Cal[a-z]fornia.

For columns which were binned, an option menu of values appears, instead of a text field. To ignore that column, select *Ignored* in the *Option* menu. You can use relational operators, such as >=, with these options. This means that the specified value as well as subsequent ones are selected.

In addition to numeric and string comparison operations, you can specify `Is Null`, which is true if the value is null.

To the right of each field is an additional option menu that lets you specify "And" or "Or" options. For example, you could specify "sales > 20 And < 40." You can have any number of And or Or clauses for a given column, but cannot mix And and Or in a single column.

*Scale to Filter* lets you specify whether the filtered landscape is rescaled to the size of the filtered data or remains the size of the entire data set.

Click the *Filter* button to start filtering. If you press *Enter* while the panel is active, filtering starts automatically.

Click the *Close* button to close the panel.

## The Selections Menu

The Selections menu lets you drill through to the underlying data.

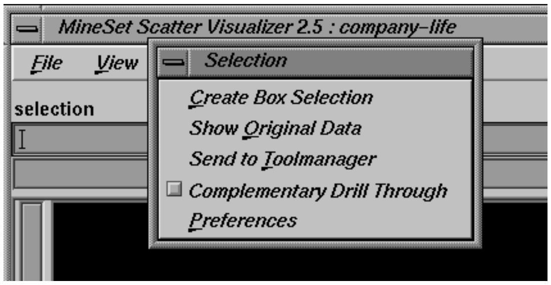


**Figure 7-12** The Scatter Visualizer Selections Menu

- *Create Box Selection* creates a 3-D box selector that can be stretched and translated to select regions of the volume. While active, a table in Record Viewer format is opened showing information about all of the aggregated data that is represented by the entities within it. Closing this window clears all current selections. Any entities within the selection box or selected using Shift-click are shown in the table window. To translate the selection box, click on one of the faces with the left mouse button, and drag it in the desired direction. Holding the Shift key while dragging constrains the motion to the axis to which the drag motion is closest. To change the extent of the selection box, drag one of the gray scale tabs in the desired direction. Trying to resize or translate beyond the bounds of the volume is not permitted. The gray scale tabs constantly resize to maintain constant screen size. If at any time they appear too big, you can zoom in closer, and they reduce their size relative to the box.
- *Show Original Data* retrieves and displays the records corresponding to what has been selected. The resulting records are shown in a table viewer.
- *Send To Tool Manager* inserts a filter operation, based on the current box selection(s), at the beginning of the Tool Manager history. The actual expression used to do the drill through is determined by the extent of the current box selection. If nothing is selected, a warning message appears.
- *Complementary Drill Through* causes the *Show Original Data* and *Send To Tool Manager* selections, when used, to fetch all the data that are not selected.

- *Preferences* brings up a panel that lets you select which columns are used in drill-through. Unlike other visual tools, there are no specific columns in the data that are designated as the key to the data. It is impossible for the Scatter Visualizer to determine which columns the user desires in the drill-through expression. For example, you might have cars data with brand, model, and weight. Perhaps you want to drill through to the original data, and specify that brand and model should be considered, but weight should not. By default, all columns that have been mapped to graphical requirements are considered significant on drill-through. The others are not, but may be made so by highlighting them in the Preferences dialog box.

For further details on drill-through, see Chapter 18, “Selection and Drill-Through.”

### The Help Menu

The Help menu is substantially the same for all visualization tools; see “The Help Menu” in Chapter 6

## Sample Configuration and Data Files

The provided sample data and configuration files demonstrate the Scatter Visualizer’s features and capabilities. The following files are in the */usr/lib/MineSet/scatterviz/examples* directory:

- *company.data*
  This file contains fictitious sales data of several insurance companies in three product categories: life insurance, auto insurance, and home insurance. The data span ten years (in increments of one year) and includes five income brackets (the customer’s annual income).
- *company.scatterviz*
  This file specifies that the years form one slider dimension and the income brackets form the other slider. Sales of life insurance, auto insurance, and home insurance become the three dimensions in the Scatter Visualizer landscape. The color density in the slider summary window represents the total sales of all companies across all categories of insurance.

- *company-total.scatterviz*
  This file contains the same specifications as *company.scatterviz*, except that the size of each company is determined by the total sales of that company across all the categories of insurance.
- *company-life.scatterviz*
  This file contains the same specifications as *company.scatterviz*, except that the color of each object indicates the life insurance sales as a fraction of total sales.
- *store-type.data* and *store-type.scatterviz*
  These files show sales of various product groups by store type during a three-year period. The single independent variable for which a slider appears is time. Each entity represents a store type (such as Food Store, Drug Store, Service Station, and so forth). For each store type, the data file contains the total sales of several product groups, such as alcoholic beverages, cereal, and so forth. The data spans 36 months, in increments of one month.

  The configuration file uses the month as the single slider dimension. One axis is sales of alcoholic beverages, the other is sales of tobacco products. A third axis is not used.

  **Note:** The data file includes other categories. You can edit the configuration file to use other product categories for the axes (see Appendix D, “Creating Data and Configuration Files for the Scatter Visualizer”).
- *brand.data* and *brand.scatterviz*
  These files show sales of several soft-drink brands in a variety of store types. In this dataset the brands form the entities, and the store types are associated with the axes. The total sales are mapped to the size of each brand. The color mapping is random. Since there are no independent variables, no slider is present.
- *cars.data* and *cars.scatterviz*
  These files show the weight, horsepower, model year, and acceleration of several car models.
- *people.data* and *people.scatterviz*
  These files show the height, weight, density, and cholesterol level for a population sample.
- *nl.births.data* and *nl.births.scatterviz*
  These files show birth patterns in the Netherlands. For each region, the population density, birth rate, and population are shown. The animation sliders are mapped to the age of the mother and the year.

- *adult94.data* and *adult94.scatterviz*
  These files show a complex example with scatterviz applied to */usr/lib/MineSet/data/adult.data*. The three axes in the visualization are avg_hrswk (that is, average hours worked per week), avg_gross_income, and avg_education_num. Unfortunately "education num" does not correspond exactly to number of years of education, but it is close. The slider on the right side animates across different age ranges. Each aggregate was created by grouping by occupation, race and sex. This means that there is an entity for every combination of values for these three attributes. The color shows different occupations, as shown in the legend. The size of each entity corresponds to record counts. The summary slider is also colored by data density. To find out how this visualization was created, you may select Start Tool Manager from the File menu. This will bring up the Tool Manager with the session used to create this example.

  Initially the scene shows information for people under 20 years of age. Note that the average hours worked (about 14) and the average income (about $4000) are low. If you animate over age using the slider, and examine the scene from the three orthogonal viewer (try using the lower 3 buttons to the right of the main window), you will notice various trends emerge. For example, if you orient the scene so you see only income by hours per week, you can see that people start to work longer hours as they age, until about age 25, then they seldom work more that 49 hours per week until they retire. Income, however, grows until people age 50, then plateaus, then goes lower again. The actual trend depends somewhat on the career choice and other factors.

  Suppose you were interested in comparing trends between the occupations craft-repair and prof-specialty. Open the Filter panel (View > Show Filter Panel) and select just "craft-repair" and "prof-specialty" from the list of occupations. Now when you animate, you can see that "prof-specialty" actually starts with lower incomes, but quickly outpaces "craft-repair" as people age. "Prof-specialty" is much higher on the education axis than "craft-repair". You may wish to limit your filter further by showing just females, or those of a certain race.

*Chapter 8*

# Using the Splat Visualizer

This chapter discusses the features and capabilities of the Splat Visualizer. It provides an overview of this database visualization tool, then explains the Splat Visualizer's functionality when working with the

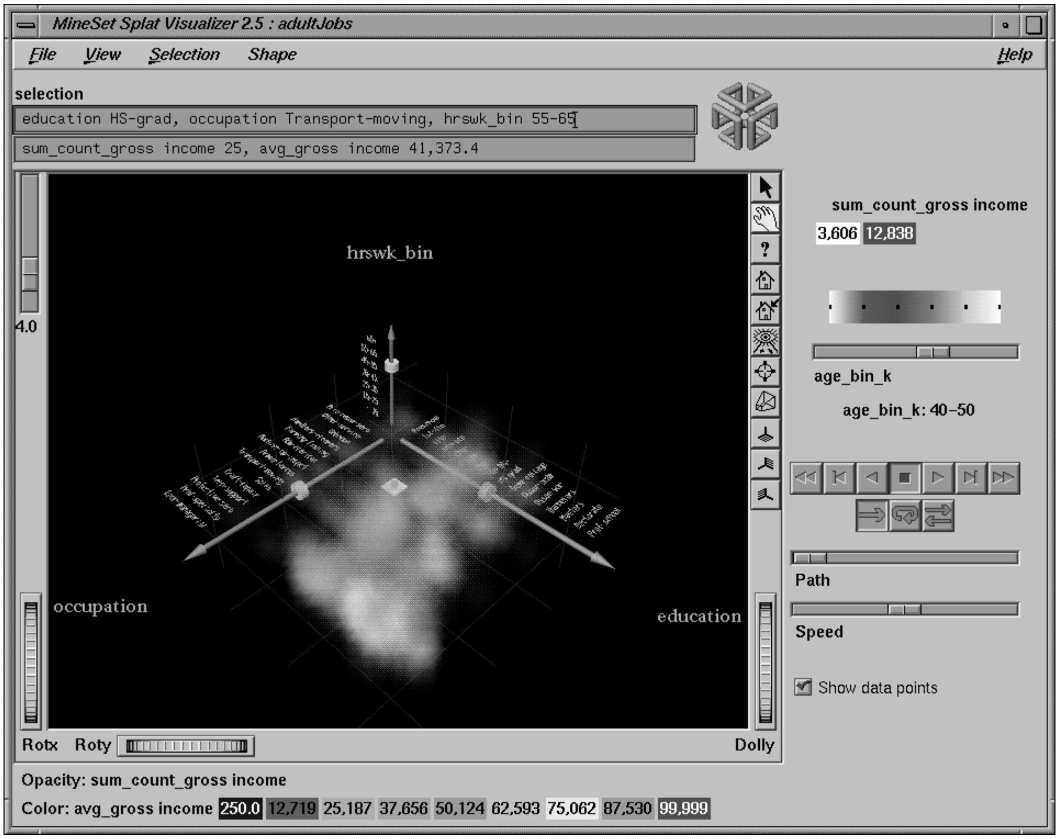
- main window
- external controls
- pulldown menus

Finally, it lists and describes the sample files provided for this tool.

## Overview of the Splat Visualizer

The Splat Visualizer lets you visually analyze relationships among several variables (see Figure 8-1), either statically or by animation. It is particularly well-suited for application to datasets with large numbers of records. Choose the Scatter Visualizer if you want to see individual data points and do not have a large number of records. Data analysis is done using

- a three-dimensional landscape
- an animation control panel that includes a two-dimensional slider
- graphical objects, called *splats*, which represent aggregates of datapoints. Color and opacity of the splats can change during animation.



selection

education HS-grad, occupation Transport-moving, hrswk_bin 55-65

sum_count_gross income 25, avg_gross income 41,373.4

sum_count_gross income 3,606 12,838

age_bin_k

age_bin_k: 40–50

☑ Show data points

Opacity: sum_count_gross income

Color: avg_gross income 250.0 12,719 25,187 37,656 50,124 62,593 75,062 87,530 99,999

**Figure 8-1** Sample Splat Visualizer With One Slider Control

The Splat Visualizer lets you visualize your data by mapping columns to axes, sliders, color, and opacity. The resulting three-dimensional landscape can be thought of as an approximation to a scatterplot in which every datapoint is drawn separately. It is not truly a scatterplot, because datapoints that are close together (fall in the same bin) are aggregated and drawn as a single splat.

Each numeric column that is mapped to an axis or slider first must be binned. If this binning step is skipped, the Tool Manager does it using automatic uniform binning (see "The Bin Columns Button" in Chapter 3). String columns can be mapped directly to axes. Any numeric column can be mapped to a color. The color of a splat is derived by averaging the value of the column mapped to color for all the data points that fall in a bin. The opacity of a splat is based on a weighting of the number of datapoints that fall in a bin. If nothing is mapped to opacity, record counts are used to determine it. The interactivity of the resulting visualization is independent of the number of data points represented; it depends only on the number of bins in the axis dimensions. If your dataset is very large, aggregate explicitly in the Tool Manager. This causes the server to perform the processing, rather than having the entire dataset sent to the client and aggregated there.

Up to two numeric columns can be mapped to the sliders in the animation control panel. The splats change their color and opacity during animation as the sliders in the animation panel are moved from point to point along the slider 's path. Unlike the Scatter Visualizer, neither the position nor the size of the splats change; they are at fixed, uniformly spaced positions. Only their color and opacity change, which can give the illusion of actual movement.

After creating a visualization of your data, the Splat Visualizer lets you analyze the data in various ways:

- The animation control panel lets you note global shifts and trends in the data.
- The three-dimensional landscape lets you orient the display to emphasize particular dimensions or a point of view.
- You can use the scale slider (located to the left of the Main Window) to lower the overall opacity of the splats, so only regions with dense data show up; conversely, you can increase the scale slider so all regions having any data become visible. The regions with dense data are likely to show less color variation, because the color is based on the average of many values (see Figure 8-3).
- You can filter the display to show only those splats meeting certain criteria. You can filter on the columns corresponding to axes, sliders, weight, and color.
- An opaque pick dragger lets you display textual information about individual splats in the volume.
- A box selector lets you define a selected region for drilling through to the original data or for sending to the Tool Manager.

If a string column is mapped onto an axis, binning is defined to be the distinct values of that column. The order of the values along a string axis is automatically determined by sorting the distinct values by the average aggregate value of the column mapped to color. Looking at the color changes along a string-valued axis lets you see how well that column correlates with the column mapped to color. The left axis in Figure 8-1 shows occupations sorted by average income (the average income of everyone with that occupation) along an axis. The occupation, executive-managerial, listed at the end of the axis, has the highest average income. This ordering often presents a natural progression for the values. For example, the ordering for the values of *education* (the right axis in Figure 8-1) was generally from low to high; but, in a few cases, there were anomalies in the order. This unexpected ordering might be interesting because it points out places where the data does not agree with expectations.

## Opacity

The column mapped to opacity should be record count or a column used to weight record counts. A splat's opacity, α, is based on this column according to the following relation:

$$\alpha = 1 - e^{-u \cdot weight}$$

where *count* is the column mapped to opacity (or the record count if no such column was mapped to opacity). The shape of this function is such that the opacity asymptotically approaches 1 (totally opaque) as the value of *weight* becomes large. The variable *u* is what is scaled when you adjust the opacity scale slider. Figure 8-2 shows the shape of this function for low and high values of *u*. Figure 8-3 shows the same visualization with low and high values of u.

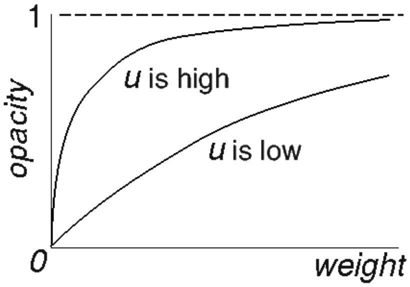
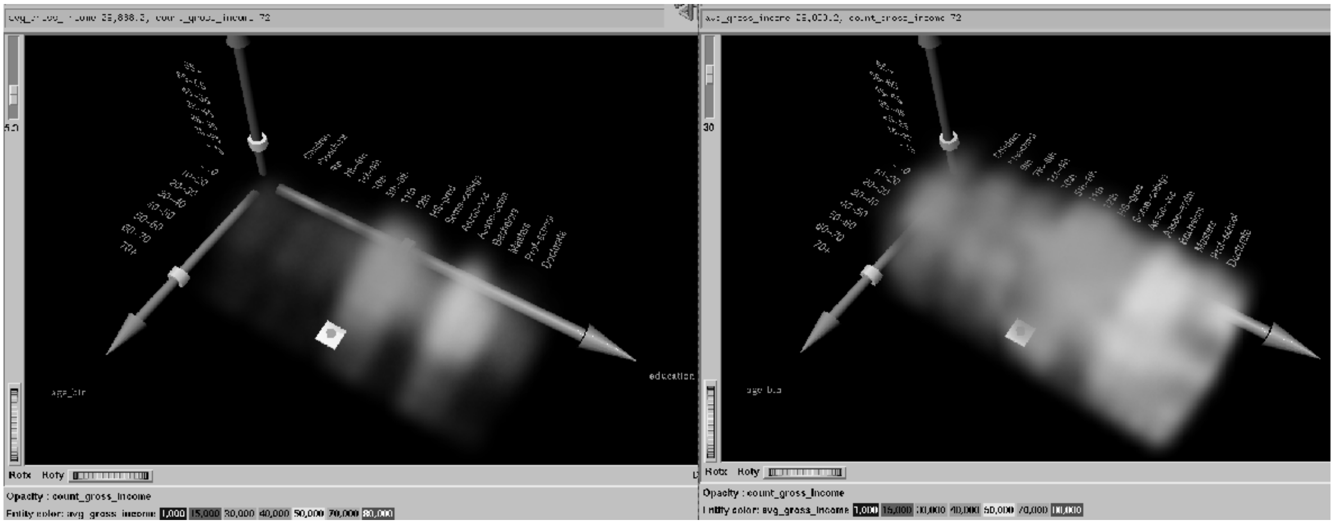


**Figure 8-2** Shape of Opacity Function For Low and High Values of *u*



avg_gross_income 25,838.2, count_gross_income 72

Opacity : count_gross_income

Entity color: avg_gross_income 1,000 15,000 30,000 40,000 50,000 70,000 80,000

avg_gross_income 25,838.2, count_gross_income 72

Opacity : count_gross_income

Entity color: avg_gross_income 1,000 15,000 30,000 40,000 50,000 70,000 80,000

**Figure 8-3** Image Where $u$ = 5.3, and $u$ = 30

If nothing is mapped to opacity, the Splat Visualizer generates a column of ones to produce record counts when aggregating. This means all records are weighted equally. A sum aggregation is done on this column, and an average aggregation is done on the column mapped to color while grouping by all the axis and slider columns. All other columns are unnecessary and removed. You do not need to map anything to opacity unless you want each record to be weighted by something other than 1.

You can avoid processing on the client by aggregating in the Tool Manager. This also avoids having to transfer a large dataset to the client. This is done by

1. Binning the numeric columns which are to be used for axes and sliders.
2. Aggregating the column to be mapped to color by count and average while grouping by the axis and slider columns.
3. Mapping the resulting count aggregation to opacity.
4. Mapping the resulting average aggregation to color.

For example, using the *adult94* data (provided with the distribution):

1. Bin age and hours_per_week.
2. Aggregate gross_income using count and average. Keep education, occupation, age_bin and hours_per_week_bin, in the group-by pane while removing all the other columns.
3. Map education, occupation, and hours_per_week_bin to the axes.
4. Map avg_gross_income to color, count_gross_income to opacity, and age_bin to a slider.

When you invoke the tool, note that all the processing is done on the server, and that the datafile, *adult94.splatviz.data*, contains rows that are aggregates of rows in the original data. This produces the same visualization as seen in Figure 8-1.

In some cases, you might have a column by which you want to weight the records. For example, if you have a dataset for which one column was population and another was average_salary (which you want to map to color), you can map population to opacity, and average_salary to color; then have the Splat Visualizer do the aggregation. Its aggregation groups-by the axis and slider columns, so that it sum aggregates the opacity column (which, in this case, is population). The new column is called sum_population. The average_salary column is revised, so that it is still average salary, but weighted by each row's population. In this way, the average salary column still shows the average salary for all the people it represents.

Alternatively, if you want to avoid client-side processing and storage because of the size of your dataset, you can perform the same aggregation in Tool Manager by doing the following:

1. Create a new column, defining temp = population*avg_income.
2. Perform an aggregation: group-by axis and slider columns, sum aggregate population, and sum aggregate temp.
3. create a new column, defining
   avg_salary = sum_temp/sum_population
   This creates the weighted average.
4. Now you can map sum_population to opacity, and avg_salary to color.

Note that these steps are the ones taken by the Splat Visualizer if you do not explicitly do them in the Tool Manager.

## File Requirements

The Splat Visualizer requires the following files:

- A data file, consisting of rows of tab-separated fields. This file is easily created using the Tool Manager (see Chapter 3). If you are generating this file yourself, see Appendix E, "Creating Data and Configuration Files for the Splat Visualizer" for the required file format.

  You can generate data files by extracting data from a source (such as a database) and formatting it specifically for use by the Splat Visualizer. Data files have user-defined extensions (the sample files provided with the Splat Visualizer have a *.data* extension).

- A configuration file, describing the format of the input data and how it is to be displayed. The Tool Manager can create this file (see Chapter 3), or you can use an editor (such as jot, vi, or Emacs) to produce this file yourself (see Appendix E, "Creating Data and Configuration Files for the Splat Visualizer").

  Configuration files must have a *.splatviz* extension. When starting the Splat Visualizer, or when opening a file, you must specify the configuration file, not the data file.

## Starting the Splat Visualizer

There are five ways to start the Splat Visualizer:

- Use the Tool Manager to configure and start the Splat Visualizer. (See Chapter 3 for details on most of the Tool Manager's functionality, which is common to all MineSet tools; see "Configuring the Splat Visualizer Using the Tool Manager" on page 256 for details about using the Tool Manager in conjunction with the Splat Visualizer.)

- Double-click the Splat Visualizer icon, which is in the MineSet page of the icon catalog (or on your Indigo Magic desktop). The icon is labeled *splatviz*. Since no configuration file is specified, the start-up screen requires you to select one by using File > Open.

  Starting the Splat Visualizer without specifying a configuration file causes the main window to show the copyright notice and license agreement for this tool. Only the File and Help pulldown menus can be used. For the main window to be fully functional, open a configuration file by selecting File > Open.

- If you know what configuration file you want to use, double-click the icon for that configuration file. This starts the Splat Visualizer and automatically loads the configuration file you specified. This works only if the configuration filename ends in *.splatviz* (which is always the case for configuration files created for the Splat Visualizer via the Tool Manager).
- Drag the configuration file icon onto the Splat Visualizer icon.
- Start the Splat Visualizer from the UNIX shell command line by entering this command at the prompt:

  ```
  splatviz [ configFile ]
  ```

  *configFile* is optional and specifies the name of the configuration file to use. If you don't specify a configuration file, you must use File >Open to specify one.

### Options for Invoking the Splat Visualizer

The **-quiet** option eliminates the dialogs that popup to indicate progress. You can enable this option permanently by adding the line

```
*minesetQuiet:TRUE
```

to your *.Xdefaults* file.

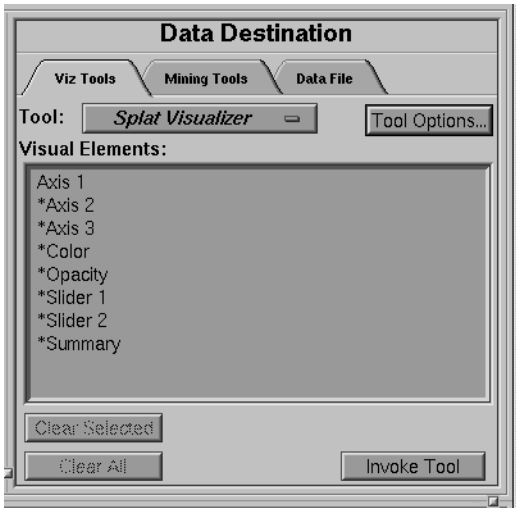
## Configuring the Splat Visualizer Using the Tool Manager

This section describes how the Splat Visualizer can be configured using the Tool Manager. Although the Tool Manager greatly simplifies the task of configuring the Splat Visualizer, you can construct a configuration file manually for this tool using a text editor (see Appendix E, "Creating Data and Configuration Files for the Splat Visualizer").

The steps required to connect to a data source are described in Chapter 3.

## Selecting the Splat Visualizer Tool

Select the *Viz Tools* tab in the Data Destination panel of the Tool Manager’s main screen (Figure 8-4). From the popup list of tools, select *Splat Visualizer*. The mapping requirements for the Splat Visualizer are displayed in the window on the right side of this panel. Items in the Visual Elements list that are preceded by an asterisk are optional.



Tool: Splat Visualizer

Visual Elements:

Axis 1
*Axis 2
*Axis 3
*Color
*Opacity
*Slider 1
*Slider 2
*Summary

**Figure 8-4** Data Destination Panel With Splat Visualizer Selected

- *Axis 1*, **Axis 2*, **Axis 3* — determine which columns are assigned to the axes in the Splat Visualizer’s main window. Assigning data to the first axis is required; however, this alone does not usually produce a useful display. By assigning data to Axis 2, you can create an XY chart. Assigning data to all three axes produces a 3-D chart.
- **Color* — Requires a numeric column used to determine the color of the splats. If you have a two-valued string column, you can create a new numeric column using an expression such as:
  ('stringCol'==”value1”)? 1:0

  If nothing is mapped to color, the resulting scene is monochromatic.

- **Opacity*—the tool was designed to have the opacity based on a weighting of records. If you do not aggregate in the Tool Manager, this requirement need not be mapped; it will be determined automatically by the tool. If you do a count aggregation in the Tool Manager, or there is a column in the data that already is based on counts, use that column for this requirement.
- **Sliders* — the summary slider dimensions. They must be numeric or binned.
- **Summary*—this is the value to be shown in the summary slider. If no summary column is mapped, count is used by default. If a summary column is mapped, a weighted average value for that column is shown in the summary.

### Mapping Columns to Requirements

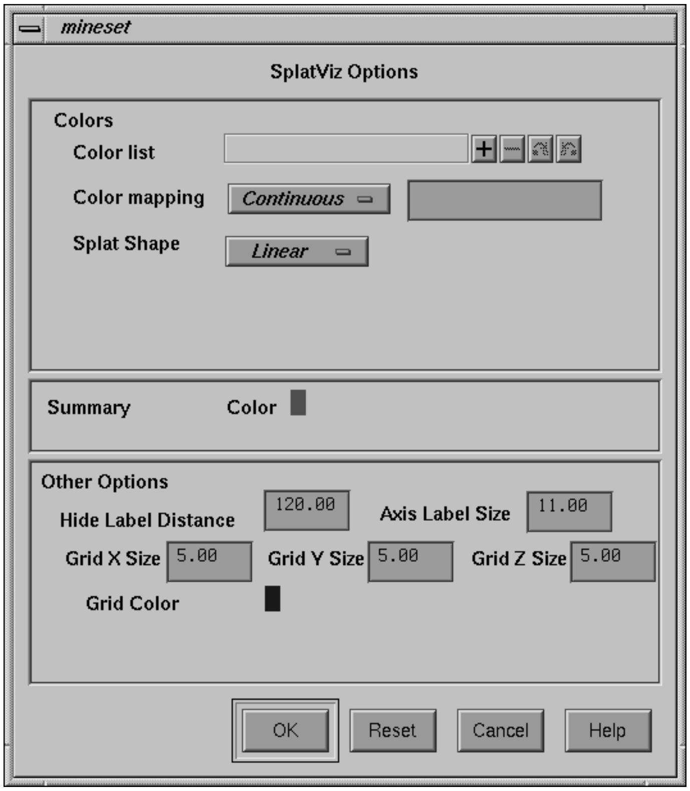
You can map requirements to columns by selecting a column name in the Current Columns window of the Table Processing panel, then selecting a category in the Visual Elements window.

### Undoing Mappings

To undo a specific mapping, select that mapping in the Requirements window, then click the *Clear Selected* button. To undo all mappings, click the *Clear All* button.

### Specifying Tool Options

Clicking the *Tool Options* button causes a new dialog box to be displayed (Figure 8-5). This lets you change some of the default values of the Splat Visualizer options.



SplatViz Options

Colors

Color list

Color mapping: Continuous

Splat Shape: Linear

Summary  Color ■

Other Options

Hide Label Distance: 120.00

Axis Label Size: 11.00

Grid X Size: 5.00

Grid Y Size: 5.00

Grid Z Size: 5.00

Grid Color ■

**Figure 8-5** Splat Visualizer′s Options Dialog Box

The Splat Visualizer′s Options dialog box has three basic options blocks:

- Splats
- Summary
- Other

### Splat Options

This option lets you specify a number of characteristics for the Splats that the Splat Visualizer then graphically displays.

- *Splat Colors*—lets you control the colors used for the splats. You can
  - specify the list of colors to use
  - specify the kind of mapping
  - map the list of colors to a list of values
- *Splat Shape*—lets you choose one of the following methods for drawing splats: linear, gaussian, texture, sphere, cube, or diamond. See “Splat Type Menu” on page 282 for a further explanation of each of these.

To use these Colors options, you must have mapped a column to the *color requirement of the Data Destination panel. If nothing is entered in the color list, the default colormap is used. The default colormap is a continuous spectrum from blue (lowest value) to red (highest value). See “Choosing Colors” and “Using the Color Browser” in Chapter 3 for a more detailed explanation of how to choose and change colors.

**Color list—**You can specify the color list using the + button next to the color list label. This brings up a color editor that lets you specify a color to be added to the list.

**Color mapping—**You can specify whether the color change that is shown in the graphic display is *Continuous* or *Discrete*. If you choose Continuous, the color values shift gradually between the colors entered in the *Color list to use* field as a function of the values that are mapped to those colors in the *Color mapping* field.

The field to the right of the popup button lets you enter specific values for mapping the colors. If you do not specify any mapping values, the range of values in the color column is used.

#### Example 8-1

If you

- used the Color Browser to apply red and green to the splats
- selected *Continuous* for the *Kind of mapping*
- entered the values `0 100`

the display shows all splats with values less than or equal to 0 as completely red, those with values greater than or equal to 100 as completely green, and those between 0 and 100 have a color which results from a linear interpolation between red and green.

#### Example 8-2

If you

- used the Color Browser to apply red and green to the splats
- selected *Discrete* for the *Kind of mapping*
- entered the values `0 50`

The display shows all splats with values of less than 50 in red, and all those with values greater than, or equal to, 50 in green.

### Summary Options

Summary options let you specify what color to use for the Summary window. This is only applicable if you have mapped a column to the summary.

#### Other Options

The Other Options, at the bottom of the dialog box, include the following fields:

- *Hide Label Distance* — controls the distance at which axis tick labels (for string valued axes) become invisible. Increase this number to make the labels appear at further distances. The higher the number, the greater the distance at which labels are hidden.
- *Axis Label Size* — this controls the size of the axis labels. A smaller number decreases the size, a larger one increases it.
- *Grid Color* — lets you modify a grid color by clicking on it. This causes the Color Chooser dialog box to appear, which lets you implement your color changes.
- *Grid (X, Y, Z) Size* — lets you specify the spacing between grid lines for the respective axis. A smaller number decreases the size, a larger one increases it. If the Size is set to 0, there are no grid lines in that dimension.

#### Resetting the Tool Options

Clicking the *Reset Options* button resets the values of all options to their default values.

### Invoking the Splat Visualizer

To see Splat Visualizer graphically represent your data, click *Invoke Tool* at the bottom of the Data Destination panel.

### Saving the Splat Visualizer Settings

When you press *Invoke Tool*, The Tool Manager stores information for the Splat Visualizer in several files, all sharing the same prefix:

- *<prefix>.splatviz.data* contains data.
- *<prefix>.splatviz.schema* describes the data file.
- *<prefix>.splatviz* contains information required by the Splat Visualizer.

To save the entire session along with the current tool options, use one of these menu options from the File menu:

- *Save Current Session...* where the default prefix is based on the data source
- *Save Current Session As...* to specify your own prefix

The saved file is <*prefix*>*.mineset,* and contains all the information needed to return MineSet to its current state.

When you use *Invoke Tool*, the *.data*, *.schema*, and *.splatviz* files are updated, if necessary.

## Null Handling in the Splat Visualizer

The Splat Visualizer uses special representations when fields with unknown data values, or nulls, are mapped to visual attributes. (For a discussion of null values, see Appendix J, "Nulls in MineSet.") When every record in a bin has a null value for the column mapped to color, the resulting color for that splat is gray. If one or more records in the aggregate have non-null values for the column mapped to colors, then that value is (or those values are) used to compute the color. While the sum of a value and null is null, the average of a value and null is the value (that is, value + Null = Null; avg(val, Null) = val).

When a null value is displayed in the Pick Window, Selection Window or "Pointer is Over" area, it is shown as a question mark (?). (The Selection Window and "Pointer is Over" areas are discussed in the "Select Mode" section.)

For numeric columns containing nulls which are mapped to axes, there is a special null position below the range defined by the axis. This is to help show that the null value is discontinuous with the other values. The null positions for numeric axes can be turned off using the Show Null Positions option under the View Menu (see "The View Menu" on page 276). For string-valued columns mapped to axes, nulls (represented by a '?') are treated as just another value.

## Working in the Splat Visualizer’s Main Window

If you started the Splat Visualizer without specifying a configuration file, the main window shows the copyright notice and license agreement for the Splat Visualizer. Only the File and Help pulldown menus can be used. For the main window to show all menus and controls, open a configuration file. Use File > Open to see a list of configuration files.

When a valid configuration file has been selected, the 3-D landscape it specifies is visible.

### Viewing Modes

The two modes of viewing are *grasp* and *select*. To toggle between these modes, press *Esc*, or click the appropriate cursor button adjacent to the top-right of the viewing area.

#### Grasp Mode

In *grasp* mode, the cursor appears as a hand. This mode supports panning, rotating, and scaling the scene’s size in the main window.

- To pan the display, press the middle mouse button and drag it in the direction you want the display panned.
- To rotate the display, press the left mouse button and move the mouse in the direction you want to rotate. (Also see the thumbwheel controls *Rotx* and *Roty*, described in “Thumbwheels” in Chapter 6.)
- To move the viewpoint forward, press the left and middle mouse buttons simultaneously and move the mouse downwards. To move the viewpoint backward, press the left and middle mouse buttons simultaneously and move the mouse upwards. This is equivalent to the functions provided by the Dolly thumbwheel.

### Select Mode

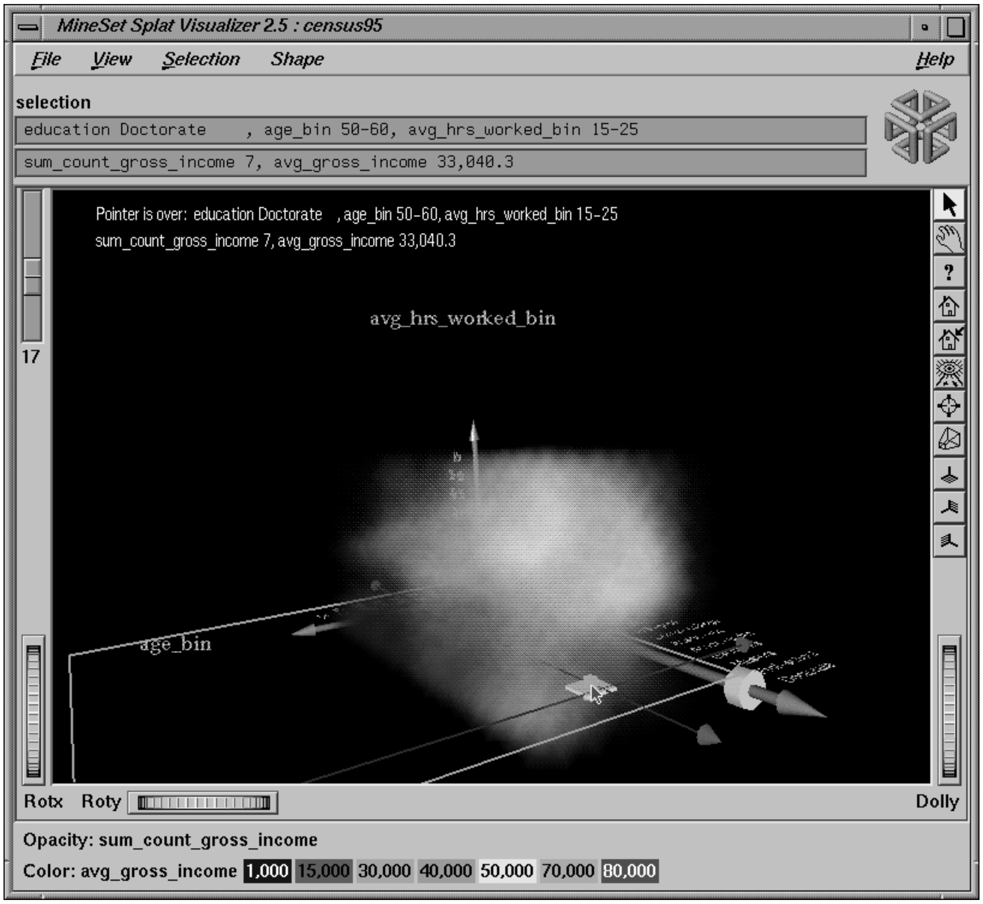
In *select* mode, you can move a 3-D pick dragger through the volume in order to display information about regions in the scene. This pick dragger is composed of a cylinder and a square. If you pick on the cylinder and drag, motion is constrained to be parallel to the cylinder's axis. If you pick on the square and drag, motion is constrained to the plane defined by the square. You can cycle through the three possible orientations of the pick dragger by pressing the *Control* key with the cursor over the dragger. (You need not press the mouse button.) In the case of dragging the square portion of the dragger, you can use the *Shift* key to constrain the motion along one of the two axes within the plane. Alternatively, each axis has a disk that aligns with the pick dragger position. Moving the disk on an axis moves the dragger, and vice-versa.

The dragger lets you pick within a dense cloud of points, freeing you from the limitation of having to pick regions on the surface.

When the pick dragger is over data, the cylinder changes its color to that of the splat under it, and information about that region appears at the top of the view area (Figure 8-6). If no data is present, the cylinder remains light gray, and information about its position is displayed at the top of the render area for aid in navigation.

When you are finished dragging, and have released the mouse button, the message for the splat you are currently over is shown in the Pick Window at the top. This pick information is updated if the animation slider is moved. Using the mouse, you can cut and paste this selection information into other applications, such as reports or databases.

The pick dragger may be removed from the scene by unchecking Selection > Show Pick Dragger.



```
education Doctorate    , age_bin 50-60, avg_hrs_worked_bin 15-25
sum_count_gross_income 7, avg_gross_income 33,040.3
```

Pointer is over: education Doctorate , age_bin 50-60, avg_hrs_worked_bin 15-25
sum_count_gross_income 7, avg_gross_income 33,040.3

Opacity: sum_count_gross_income

Color: avg_gross_income 1,000 15,000 30,000 40,000 50,000 70,000 80,000

**Figure 8-6** Pick Dragger Over Data

The information is displayed when the pick dragger is over the object.

**Note:** Users familiar with Open Inventor can configure the Splat Visualizer so that the right mouse button brings up the standard Inventor Menu. This provides additional functions, such as stereo viewing and spin animation. These functions are provided by the Open Inventor library. To enable the Open Inventor Menu, add the line
`*minesetInventorMenu:TRUE`
to your *.Xdefaults* file.

## External Controls

Several external controls surround the main window, including buttons and thumbwheels. (These and the rest of the buttons are substantially the same as the other MineSet visualization tools and are described in “Buttons” in Chapter 6, and “Thumbwheels” in Chapter 6).

## The Animation Control Panel

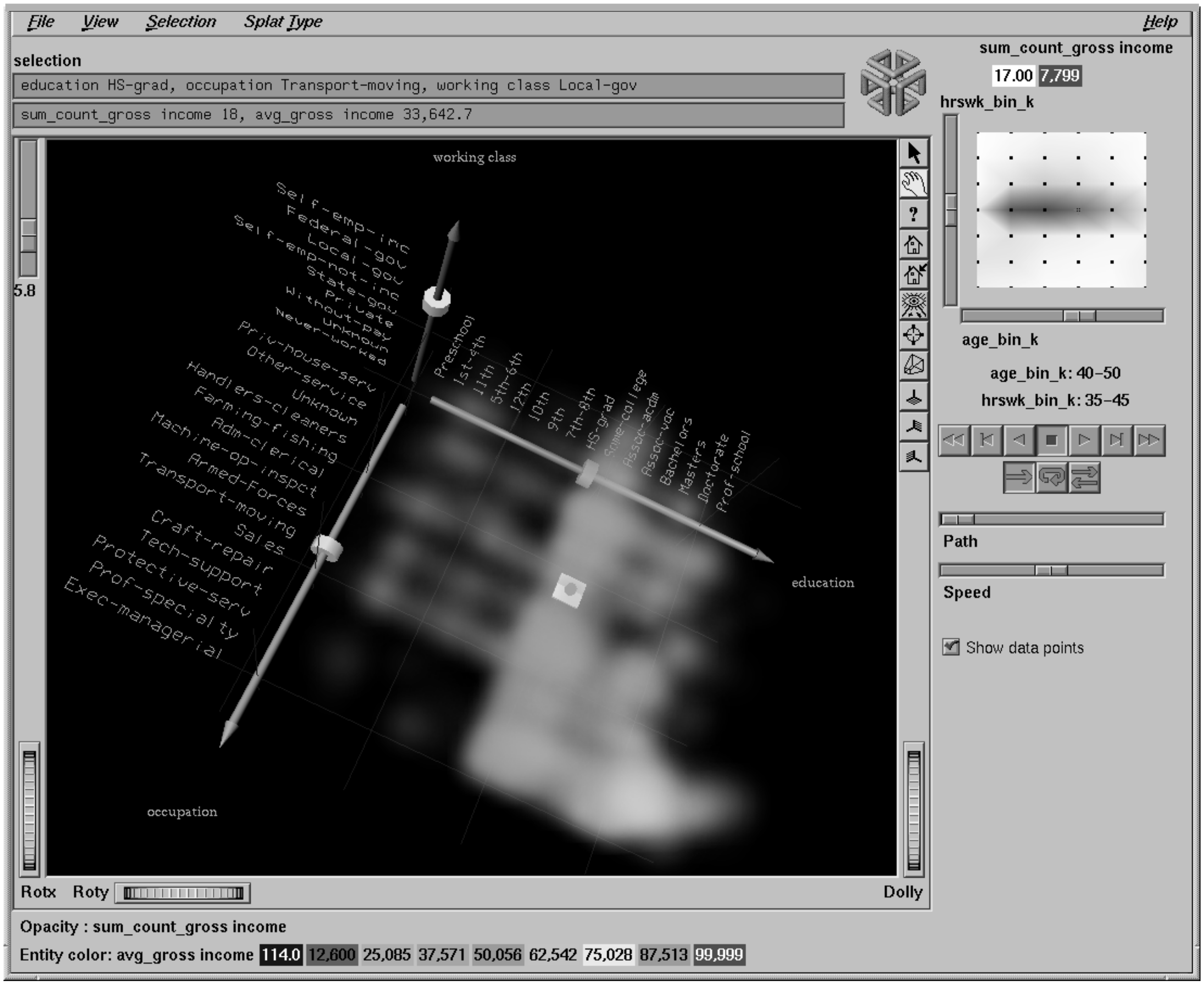
The animation control panel, which appears to the right of the main window, consists of a summary window, with up to two adjacent sliders, an information field, animation buttons, and animation sliders.

### Sliders Controlling Independent Dimensions

The number of sliders appearing adjacent to the summary window is dependent on the slider mappings specified in the configuration file. Datasets can have two, one, or no independent dimensions.

#### Datasets With Two Independent Dimensions

If the dataset has two dimensions of independently varying data (such as *adultJobs2.splatviz*), the controls to the right of the main graphics window become visible (see Figure 8-7).



selection

education HS-grad, occupation Transport-moving, working class Local-gov

sum_count_gross income 18, avg_gross income 33,642.7

sum_count_gross income 17.00 7,799

age_bin_k: 40–50

hrswk_bin_k: 35–45

☑ Show data points

Opacity : sum_count_gross income

Entity color: avg_gross income 114.0 12,600 25,085 37,571 50,056 62,542 75,028 87,513 99,999

**Figure 8-7** Animation Control Panel With Summary Window and Both Slider Controls

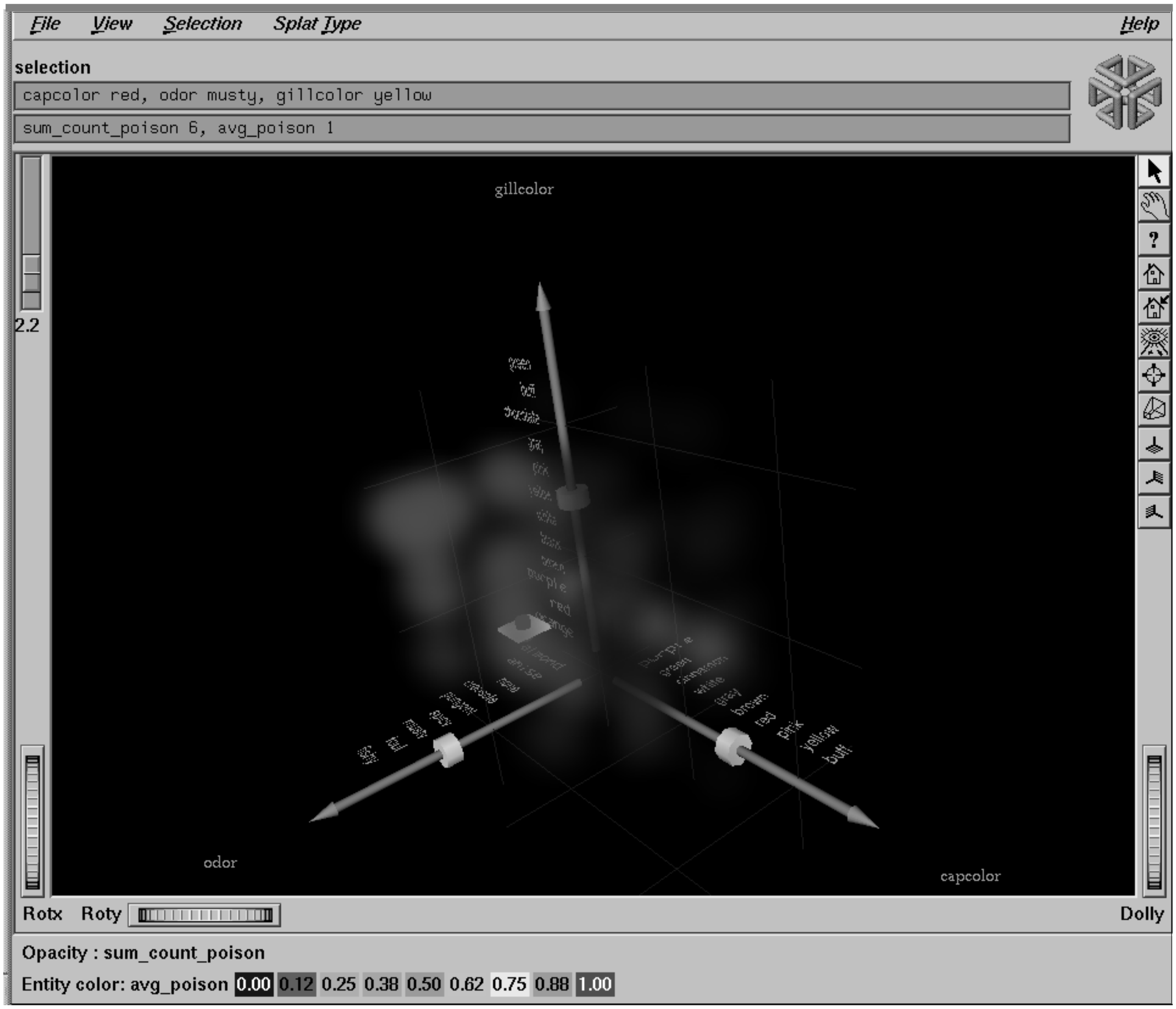
To the right of the main window are the 2-D summary window and slider controls. The summary window has a horizontal slider below it for selecting data points of the first independent dimension, and a vertical slider to the left for selecting data points of the second independent dimension. The horizontal slider's dimension is identified by a label below it. The vertical slider's dimension is identified by a label above it.

### Datasets with One Independent Dimension

For datasets with one independent dimension (such as *adultJobs.splatviz*), only the slider below the summary window appears, and the summary window is compressed (see Figure 8-1). This slider's dimension is identified by a label below it.

### Datasets With No Independent Dimension

For datasets with no independent dimensions (such as *mushroom.splatviz*), no slider control appears (see Figure 8-8). In this example, the splats that are neither completely red nor completely blue indicate that both poisonous and edible mushrooms are plotted at that location.



selection

capcolor red, odor musty, gillcolor yellow

sum_count_poison 6, avg_poison 1

Opacity : sum_count_poison

Entity color: avg_poison 0.00 0.12 0.25 0.38 0.50 0.62 0.75 0.88 1.00

**Figure 8-8** Splat Visualizer Without Independent Dimension or An Animation Control Panel

## The Summary Window

The summary window provides a 2-D representation of the aggregation of values that the main window displays in 3-D. The whiter the areas of the summary window, the lower the summary value represented by the splats in the main window. The greater the color density in areas of the summary window, the higher the summary values. The summary value is either the total weight of data at that slider position, or the weighted average of the column that was mapped to summary. The density of these colors in the summary window provides a summary of the data across the one or two independent dimensions in the dataset. If no column is explicitly mapped to summary, count is used to show which positions on the slider represent the most data.

By default, the summary window also contains a set of black dots, evenly spaced across the one or two dimensions of data. These dots indicate the precise positions of the discrete datapoints. You can turn off these black dots by unchecking the box at the bottom of the summary slider window. Slider positions between these positions use interpolation of the underlying data to produce an image.

### Color Density in the Summary Window

After opening the *adultJobs.splatviz* file, for example, the 2-D summary window shows a color range from white (on the left) to red (in the middle) to white (on the right). Red represents more records (12,838 in this case), while white represents fewer records (3,606). In this example, the greater the density of red in the middle of the slider, means the highest concentration of people are in the 20-50 age range.

### Creating a Path in the Summary Window

If the dataset loaded into the Splat Visualizer has at least one independent dimension, it is possible to view all or any part of that dataset via animation. This is done by first creating a path in the summary window (this path connects a sequence of data points), then activating the animation controls described in the next section.

The three ways to draw a path in the summary window are:

- Define a starting point by clicking and holding down the left mouse button, then draw a path by dragging the cursor over the window. End the path by releasing the left mouse button.
- Define a starting point by clicking the left mouse button, then define an endpoint by moving the cursor to another part of the window and clicking the middle mouse button. A path appears between those two endpoints. To add more line segments, continue with repeated middle mouse clicks.
- Define a starting point by clicking the left mouse button, then drag one of the independent dimension sliders, thus drawing a straight line along this dimension. If there are two sliders, use of the second slider causes a straight line to be drawn along the axis controlled by this second slider.

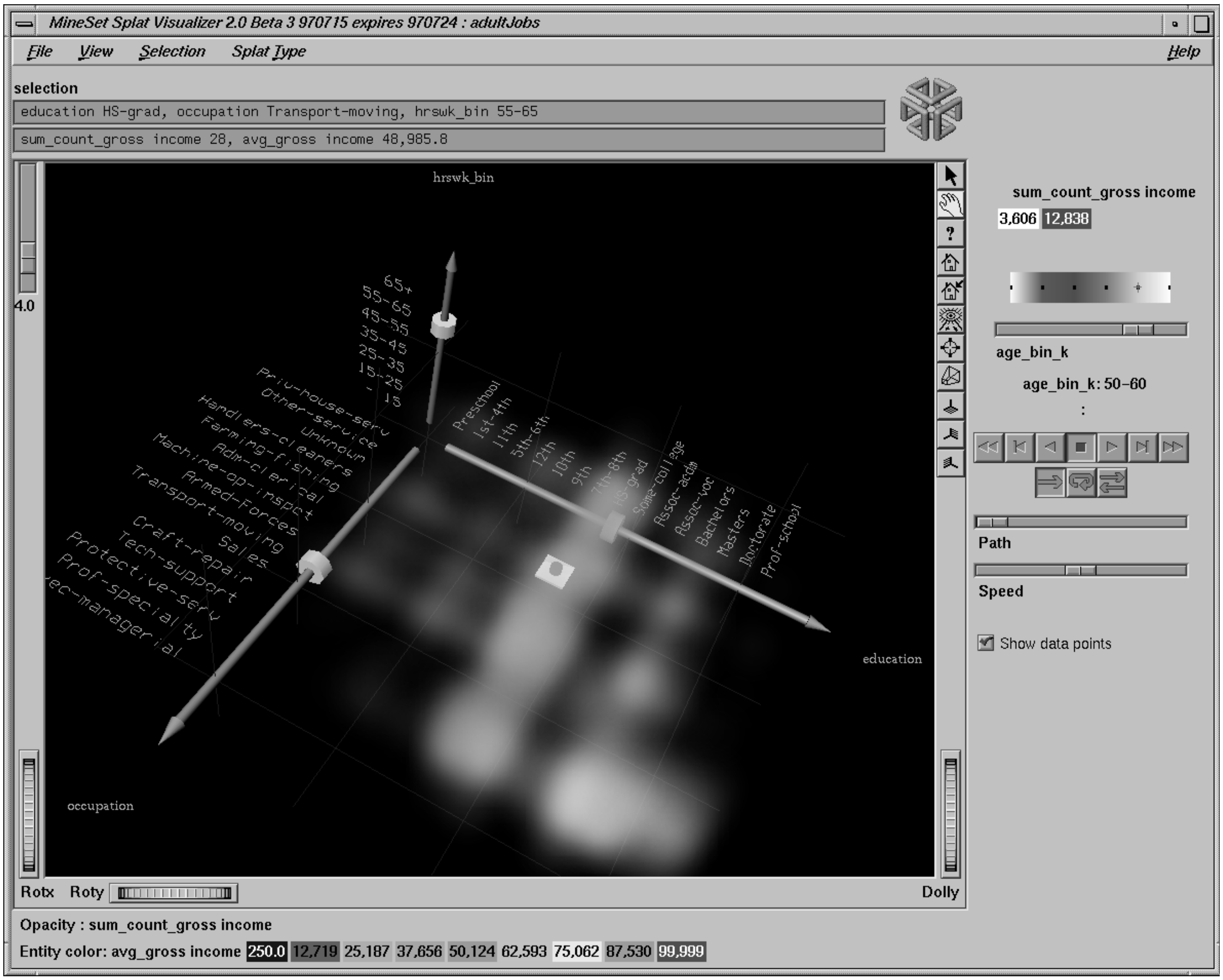
## Animation Buttons and Sliders

The animation panel is identical to that of the Map Visualizer, see "Animation Buttons and Sliders" in Chapter 6. The following section is different, however.

### Slider Data Points and Interpolation

As animation proceeds, the size and color of the splats change smoothly. The information displayed in the message box field shows the interpolated data values. When the slider motion stops, the slider position snaps to the nearest discrete data position where interpolated data values are not used.

There is a table for each binned position on the summary slider. Each row in one of these tables (which is an aggregate of original data) defines a splat in the scene. Tables corresponding to adjacent bins on the summary need not have the same number of rows because of the differences in data distribution from one position to the next. For example, if we change the visualization in Figure 8-1 from showing 40-50 year-olds to one showing 50-60 year-olds by moving the slider one notch to the right (see Figure 8-9), some positions might show splats where there were none before, and vice versa.



MineSet Splat Visualizer 2.0 Beta 3 970715 expires 970724 : adultJobs

selection

education HS-grad, occupation Transport-moving, hrswk_bin 55-65

sum_count_gross income 28, avg_gross income 48,985.8

sum_count_gross income 3,606 12,838

age_bin_k

age_bin_k: 50–60

Path

Speed

☑ Show data points

Opacity : sum_count_gross income

Entity color: avg_gross income 250.0 12,719 25,187 37,656 50,124 62,593 75,062 87,530 99,999

**Figure 8-9** Changed Visualization as a Result of Moving the Slider (Compare to Figure 8-1)

For interpolation on a one dimensional slider, two adjacent tables are merged, then aggregated using the spatial columns as unique keys. The count is simply interpolated (0 count is assumed if one of the tables lacks a particular row). The average value used for color is also interpolated, but weighted by the count.

### Example 8-3

(This example describes technical details of the interpolation process.) Suppose we want to show an image that represents an interpolation between the tables for the 40-50 year-olds and the 50-60 year-olds on the external slider. Let Table 8-1 and Table 8-2 be the tables for age=40-50 and age=50-60, respectively, for the two slider positions.

**Table 8-1** Ages 40 to 50

| education | occupation | hours_worked | income | count |
|---|---|---|---|---|
| HS-grad | Exec-Man. | 15-25 | 25000 | 2 |
| HS-grad | Mach-op | 15-25 | 30000 | 1 |
| Masters | Technician | 25-35 | 35000 | 3 |

**Table 8-2** Ages 50 to 60

| education | occupation | hours_worked | income | count |
|---|---|---|---|---|
| HS-grad | Exec-Man. | 15-25 | 70000 | 1 |
| Vocational | Mach-op | 35-45 | 40000 | 2 |

This is how the Splat Visualizer performs the interpolation. For Table 8-1, a new count column equal to *(1-t)count* and a new weighted value column equal to *(1-t) (count) (value)* are added. For Table 2, a new count column equal to *(t)(count),* and a new weighted value column equal to *(t) (count) (value)* are added. The two tables are merged together.

The merged table is aggregated using the spatial axes columns as keys, and sum aggregating the two new columns. This ensures that no two rows have the same binned values for all the spatial axes. Finally, divide the summed value by the summed count to get the interpolated values. In this case, the interpolated values are for *income*. If *t*=.5, the resulting table would be Table 8-3.

**Table 8-3** Interpolation Midway Between Table 1 and Table 2

| education | occupation | hours_worked | income | count |
|---|---|---|---|---|
| HS-grad | Exec-Man. | 15-25 | 40000 | 1.5 |
| HS-grad | Mach-op | 15-25 | 30000 | .5 |
| Masters | Technician | 25-35 | 35000 | 1.5 |
| Vocational | Mach-op | 35-45 | 40000 | 1 |

If the external query slider has two dimensions, bilinear interpolation is used.

This census dataset contains nearly 150,000 rows. The purpose of the external slider is to allow navigation through, and show summary info for additional dimensions in the data. The red regions represent places where the summary value is high; white shows areas where it is low. When the slider is positioned over a black point, the image shows uninterpolated data. One can trace a path on the slider and animate it using the VCR control panel below the slider.

To show how animation is produced, assume you have data for 8 years, 1990-1997 (that is, eight data points in the summary window). Lets examine how one splat changes as the slider is moved from one year to the next. Assume that in 1990 a splat at a given position has value of 20 (to be mapped to color) and a count of 2. Assume further that in 1991 that same splat has a value of 40 and a count of 200. The splat in year 1991 is much more opaque than the one in 1990 because it represents an aggregation of many more records (or of much more heavily weighted records). As you move the year slider from 1990 to 1991, the count changes by being linearly interpolated between 2 and 200. The value is computed by taking an average of the two values weighted by records counts (or weights). For example, midway between 1990 and 1991, the count is 101, and the value is ((1-.5)*2*20+.5*200*40)/((1-.5)*2+.5*200) = 39.8. As you approach 1992, the size approaches 40. You cannot stop an animation between discrete data points, and you cannot drag the Path slider to a stationary position between discrete data points.

The data points in the summary window represent the slider positions corresponding to the actual data from the data file. For example, values 20 and 40 represent aggregations of actual data, but the value 39.8 does not.

## Pulldown Menus

Five pulldown menus let you access additional Splat Visualizer functions. These are labeled File, View, Selection, Splat Type, and Help. If you start the Splat Visualizer without specifying a configuration file, only the File and the Help menus are available. The File and Help menus are the same as found in other MineSet visualization tools. For a description see "The File Menu" in Chapter 5, and "The Help Menu" in Chapter 5.

### The View Menu

The View menu lets you control certain aspects of what is shown in the Splat Visualizer window.

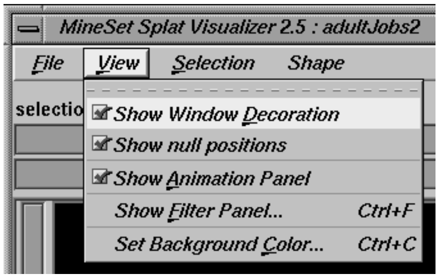
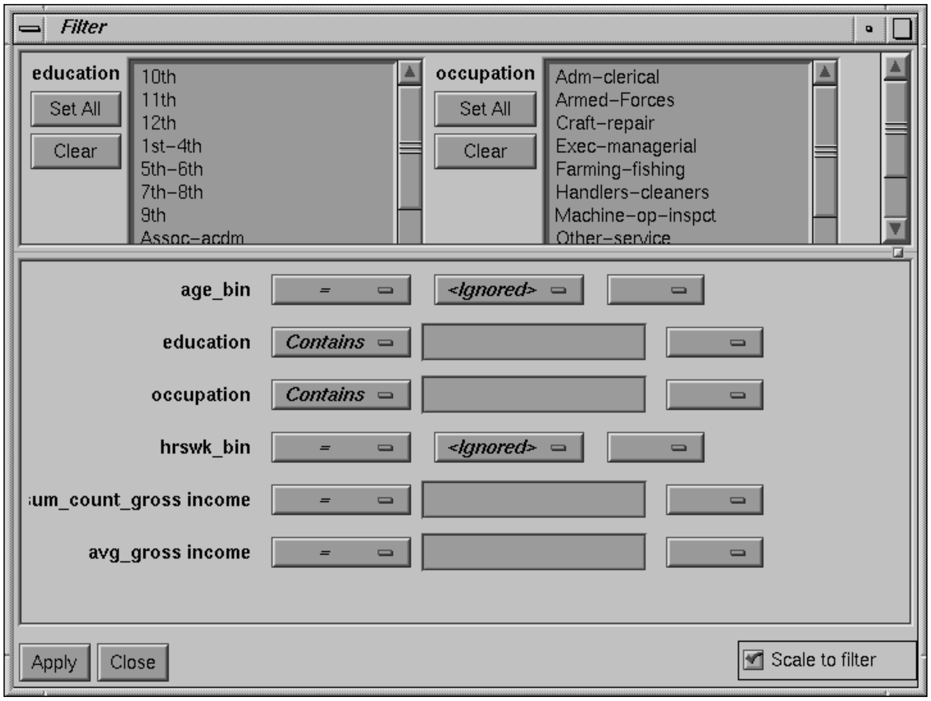

MineSet Splat Visualizer 2.5 : adultJobs2
File
View
Selection
Shape
selectio
☑ Show Window Decoration
☑ Show null positions
☑ Show Animation Panel
Show Filter Panel... Ctrl+F
Set Background Color... Ctrl+C

**Figure 8-10** Splat Visualizer View Menu

- *Show Window Decoration* lets you hide or show the external controls around the main window.
- *Show Null Positions* lets you hide or show splats that have null or unknown position values along one or more axes.
- *Show Animation Panel* lets you show or hide the animation control panel. This menu item is disabled for datasets with no independent dimension.

- *Show Filter Menu* brings up a filter panel (Figure 8-11) that lets you reduce the number of splats displayed in the main viewing area, based on one or more criteria. You can use the filter panel to fine-tune the display, emphasize specific information, or simply shrink the amount of information displayed. Columns other than those mapped to axes, sliders, opacity, and color are not available for filtering because they are removed during aggregation. The *Scale to filter* checkbox, which appears in the lower right of the filter panel, lets you specify whether the landscape in the main window covers the entire dataset or just the filtered data.
- *Set Background Color* brings up a color chooser to let you specify a new background color.



education: 10th, 11th, 12th, 1st–4th, 5th–6th, 7th–8th, 9th, Assoc–acdm

occupation: Adm–clerical, Armed–Forces, Craft–repair, Exec–managerial, Farming–fishing, Handlers–cleaners, Machine–op–inspct, Other–service

| | | | |
|---|---|---|---|
| age_bin | = | <Ignored> | |
| education | Contains | | |
| occupation | Contains | | |
| hrswk_bin | = | <Ignored> | |
| ıum_count_gross income | = | | |
| avg_gross income | = | | |

☑ Scale to filter

**Figure 8-11** Splat Visualizer Filter Panel

The Filter panel has two panes. The top pane lets you filter based on string columns. To select all values of a column, click *Set All*. To clear the current selections, click *Clear*. To select a value, click it. To deselect a value, simply click it again.

The bottom pane lets you filter based on the values of both string and numeric columns.

To filter numeric values, enter the value, and select a relational operation (=, !=, >, <, >=, <=). To filter alphanumeric values, enter the string. You can use any of three types of string comparisons:

- Contains indicates that it contains the appropriate string. For example, "California" contains the strings "Cal" and "forn".
- Equals requires the strings to match exactly.
- Matches allows wildcards:

– An asterisk (*) represents any number of characters.

– A question mark (?) represents one character.

– Square braces ([ ]) enclose a list of characters to match.

For example, California matches Cal*, Cal?fornia, and Cal[a-z]fornia.

For columns which were binned, an option menu of values appears, instead of a text field. To ignore that column, select *Ignored* in the Option menu. You can use relational operators, such as >=, with these options. This means that the specified value as well as subsequent ones are selected.

In addition to numeric and string comparison operations, you can specify `Is Null`, which is true if the value is null.

To the right of each field is an additional option menu that lets you specify "And" or "Or" options. For example, you could specify "sales > 20 And < 40." You can have any number of And or Or clauses for a given column, but cannot mix And and Or in a single column.

*Scale to Filter* lets you specify whether the filtered landscape is rescaled to the size of the filtered data or remains the size of the entire data set.

Click the *Filter* button to start filtering. If you press *Enter* while the panel is active, filtering starts automatically.

Click the *Close* button to close the panel.

## The Selection Menu

The Selection menu (Figure 8-12) lets you drill through to the underlying data. The menu has six items.

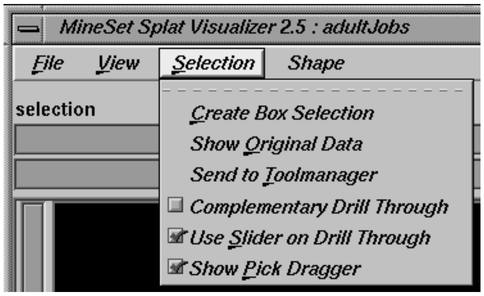
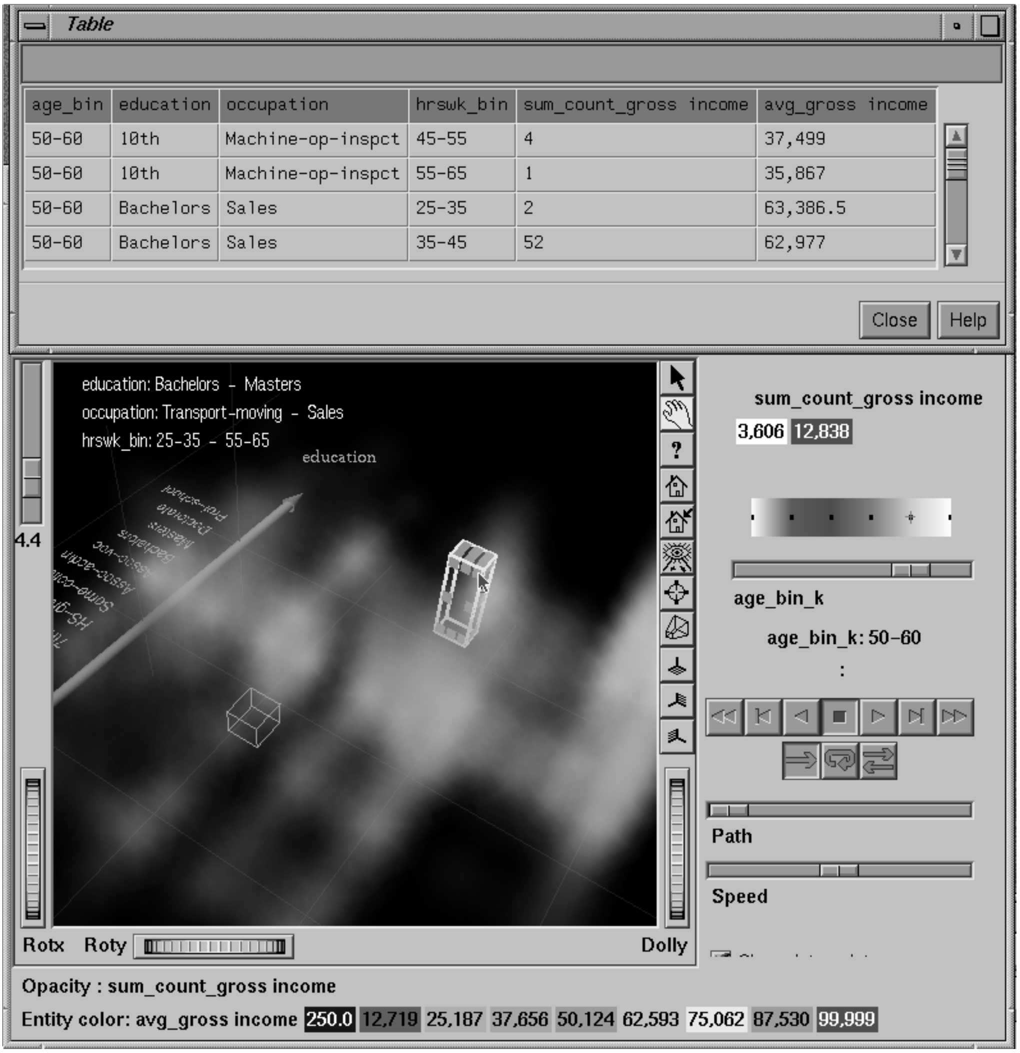


**Figure 8-12** The Splat Visualizer’s Selection Menu

- *Create Box Selection* creates a 3-D box selector that can be stretched and translated to select regions of the volume. While the box selector is active, a window in Record Viewer format is opened showing information about all of the aggregated data that is represented by the splats within it (see top of Figure 8-13). Closing this window clears the current box selection(s). Selecting this option again creates a new box selection, making the previous selection fixed. The fixed-selection boxes are gray, while the active one is light yellow (see Figure 8-13). The selected bins, shown in the selection window, are the bins enclosed by the union of all the selection boxes.



| age_bin | education | occupation | hrswk_bin | sum_count_gross income | avg_gross income |
|---|---|---|---|---|---|
| 50-60 | 10th | Machine-op-inspct | 45-55 | 4 | 37,499 |
| 50-60 | 10th | Machine-op-inspct | 55-65 | 1 | 35,867 |
| 50-60 | Bachelors | Sales | 25-35 | 2 | 63,386.5 |
| 50-60 | Bachelors | Sales | 35-45 | 52 | 62,977 |

education: Bachelors - Masters
occupation: Transport-moving - Sales
hrswk_bin: 25-35 - 55-65

sum_count_gross income
3,606 12,838

age_bin_k: 50-60

Opacity : sum_count_gross income
Entity color: avg_gross income 250.0 12,719 25,187 37,656 50,124 62,593 75,062 87,530 99,999

**Figure 8-13** Image With Fixed Selection Box (Gray) and Active Selection Box (Yellow)

To translate the active selection box, click on one of the faces with the left mouse button, and drag it in the desired direction. Holding the *Shift* key while dragging constrains the motion to the axis to which the drag motion is closest. To change the extent of the selection box, drag one of the gray scale tabs in the desired direction. Trying to resize or translate beyond the bounds of the volume is not permitted. The gray scale tabs constantly resize to maintain constant screen size. If at any time they appear too big, you can zoom in closer, and they reduce their size relative to the box.

- *Show Original Data* retrieves and displays the records corresponding to what has been selected via Box Selection(s). The resulting records are shown in a table viewer.
- *Send To Tool Manager* inserts a filter operation, based on the current box selection(s), at the beginning of the Tool Manager history. The actual expression used to do the drill through is determined by extents of the current box selection(s). If nothing is selected, a warning message appears.
- *Use Slider On Drill-Through* determines whether or not to use the slider position when creating the drill-through expression. If checked (default), an additional term is added to the drill-through expression, limiting the drill-through to those records defined by the slider's position. If this option is not checked, no such limiting term is added.
- *Complementary Drill Through* causes the *Show Original Data* and *Send To Tool Manager* selections, when used, to fetch all the data that are not selected.
- *Show Pick Dragger* toggles the visibility of the pick dragger (on by default). The pick dragger is removed when a box selection is started, but it can be made active at the same time that a box selection is active.

For further details on drill-through, see Chapter 18, "Selection and Drill-Through."

## Splat Type Menu

Splats are used in this tool to model clouds of small points (see Lee Westover, "Footprint Evaluation for Volume Rendering" in *Proceedings of SIGGRAPH '90*, Vol. 24, No. 4, pages 367-376).

The Splat Type menu lets you change the method for drawing the splats. You can choose to exchange accuracy for interactivity. Texture splats are the most accurate representation of ideal Gaussian density that is approximated in every approach. Since most computers support hardware-assisted texturing well, the texture splat is usually the best choice. Among SGI platforms, only the Indy or earlier systems are restricted to the slower software implementation. The three splat types are:

- *Linear* draws a small set of triangles to give a linear approximation to a Gaussian splat.
- *Gaussian* draws a large set of triangles to approximate a Gaussian splat.
- *Texture* uses a texture mapped rectangle to give the most accurate representation. This can be very slow on machines that don't support hardware-assisted texture mapping.

Alternatively, the following opaque primitives are allowed.

- *Sphere* draws an opaque sphere, the radius for which varies with the cube root of the count (or weight).
- *Cube* draws a large set of triangles to approximate a Gaussian splat.
- *Diamond* uses a texture-mapped rectangle to give the most accurate representation. This can be very slow on machines that don't support hardware-assisted texture mapping.

## Sample Configuration and Data Files

The provided sample data and configuration files demonstrate the Splat Visualizer's features and capabilities. The following files are in the */usr/lib/MineSet/splatviz/examples* directory:

- *mushroom*
  The *mushroom.data* file contains pre-aggregated data concerning more than 5,000 mushrooms. The group by columns were: odor, gill_color, and cap_color. For every combination of these three columns in the original data, there is a count and an average edibility, where 0 is edible, and 1 is poisonous. An average edibility between 0 and 1 means some of the mushrooms in that aggregate are edible and some are poisonous, since mushrooms can not be partially poisonous.

  The visualization (Figure 8-8) shows that the unique values for each of these columns have been sorted along the axes according to average edibility. Odor is clearly the best determinant of edibility. Also note that most splats are either all 0 or all 1, meaning these three columns are useful in segmenting the two classes of mushrooms. Lower the opacity slider to determine which splats have the highest counts. The most opaque splat represents 288 mushrooms having common values for odor, gill_color, and cap_color. To confirm this try filtering based on sum_count_poison>280 and picking on the remaining splats to see their counts. Note that all mushrooms with gill_color=buff are poisonous.

- *adultJobs*
  The *adultJobs.data* file was derived from *adult94*, a dataset provided with the distribution. It was created using an aggregation that grouped by education, occupation, hrs_worked_per_week(binned), and age (binned). The gross_income column was aggregated by count and average. For a display using the Splat Visualizer (Figure 8-1), age_bin was mapped to a slider, while the other group-by columns were mapped to axes. The count_gross_income column was mapped to opacity, and avg_gross_income was mapped to color.

  When the slider is in the left-most position, the color of the plot is almost entirely blue. This means that regardless of occupation, education, or number of hours worked, people younger than 20 have low incomes. Move the slider to the right, and note how incomes rise faster for higher education and occupations toward the end of the axis. By the opacity variation you can see that the most common types of education are HS, some college and Bachelors degree.

  Moving the Summary slider shows how the distribution of income changes with respect to the axis columns as people age.

- *adultJobs2*
  The *adultJobs2* file is also based on the *adult94* dataset. Here, the axis columns are working_class, education, and occupation. The two columns mapped to sliders are age(binned) and hours_worked_per_week(binned). Again, income was aggregated by count and average for use with opacity and color, respectively. Since there are more positions on the 2D slider, there are fewer records represented by each position. This causes greater variation of color and opacity. The red region in the center of the hrs_per_week dimension of the Summary slider shows that nearly everyone works between 35 and 45 hours per week (see Figure 8-7). Note that some occupations are aligned with specific working classes. For example, everyone in the Armed-forces has Fed-Government for their working class.
- *censusIncome*
  This example is based on a dataset similar to *adult94*, but was not included with the distribution because of its size. In attempt to understand the differences between gross income and total income, gross_income, total_income, and hrs_per_week have been mapped to axes. Color shows age. By studying the image we can learn that there are many records where total_income=gross_income, but there are also a larger portion of records with high total_income, but 0 gross_income. It is surprising that in many cases gross_income is greater that total_income.

  Note where the people of different ages are concentrated. Many old people (yellow) are in the hrs_per_wk=0 plane. They are probably retirees. Many children and young adults (blue) are in the line gross_income=total_income=0. Note the fairly opaque splats near the outside edges of the volume. These positions include all points that fell in the maximum bin shown for an axis. For example, the highest bin for total_income is 70300+. Any point higher than 70300 goes in this bin.

  To better see the varying density, adjust the opacity slider. At low opacity scales, the diagonal lines show that for most people gross_income=total_income, or they have just total_income and no gross_income. As you raise the scale, you can see that almost the entire volume contains data. This dataset contains 150,000 records.

- *churn*
  Churn is when a customer leaves one company for another. This example shows customer churn for a telephone company. The data used to generate this example is in */usr/lib/MineSet/data/churn.schema*.

  Using column importance, we found that total_day_charge, number_customer_service_calls, and international_plan were important discriminators. These columns were mapped to axes. We then created a new numeric column, churn, which equals churned==Yes, and mapped it to color.

  In the resulting visualization, red areas of the volume indicate high churn. The area corresponding to three or more customer service calls and low total_day charge corresponds to high churn. You might want to weight big-spending customers more heavily than others. To do this, create a new column, total_charge, equal to

  ```
  `total_day_charge`+`total_eve_charge`+`total_night_charge`
  ```

  or some power of this sum. Then map this total_charge column to opacity. This means every record is weighted by total_charge. Now the visualization shows additional areas of interest near the high end of the total_day_charge axis.

*Chapter 9*

# Using the Rules Visualizer

This chapter discusses the components and capabilities of the Rules Visualizer. It first provides an overview of this data mining and visualization tool, then it explains this tool’s functionality when working with the

- main window
- external controls
- pulldown menus

Finally, it lists and describes the provided sample files for these tools.

## Overview of Rules Visualizer

The Rules Visualizer gives you the power to mine data by constructing, verifying, and graphically representing models of patterns in large databases. These patterns are expressed via association rules, which indicate the frequency of items occurring together in a database.

Discovering and graphically displaying association rules can be relevant to many enterprises, including supermarket inventory planning, shelf planning, and attached mailing in direct marketing.

The tool execution scenario described in Chapter 1 of this document (see Figure 1-1) is slightly modified for the Rules Visualizer. First, the “raw” data in your database must be converted into a specially formatted file that can be processed by the association rules generator part of the Rules Visualizer. When the association rules generator has processed this file, the results can be displayed by the rules visualizer part of this tool.

Thus, the Rules Visualizer consists of three operations:

1. Data conversion. The association data converter processes a “raw” data file and creates a file usable by the association rules generator.
2. Association rules generation. The data file created by the association data converter is processed by the association rules generator, which creates a file usable by the rules visualizer.
3. Rules visualization. This operation displays the generated association rules.

In addition to the input data and rules file requirements, each operation requires a configuration file that specifies operational parameters.

The sequence of actions by the user, at the user’s workstation, and at the host server is shown schematically in Figure 9-1. The phases indicated at the right of the illustration correlate to the operations listed above.

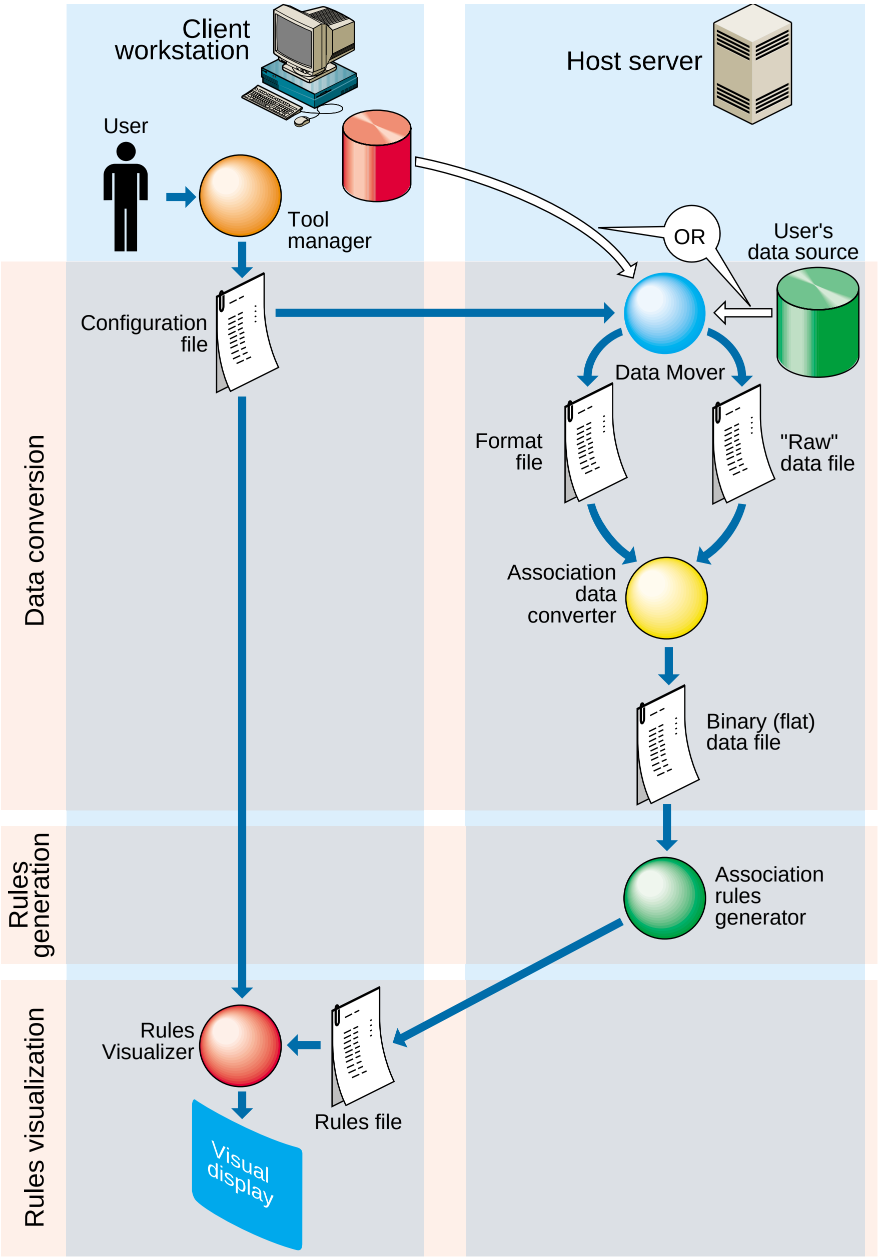


**Figure 9-1** Execution Sequence of the Rules Visualizer

## Data Conversion

The association data converter takes a “raw” data file, such as one resulting from a database query, and creates a binary data file in the format used by the association rules generator. The internal format of this generated file allows optimum processing by the rules generator. The data converter also accepts input from flat files as well as databases.

## Association Rules Generator

One example of applying the association rules generator is to obtain “market basket” data for customer buying patterns. Here, “market basket” is the set of items bought by each customer on a single visit to a store. An example rule in this context might be: “80% of the people that buy diapers buy baby powder.” This percentage is known as the *predictability* of the rule.

In the example, “diapers” is the item on the left-hand side (LHS) of the rule, and “baby powder” is the item on the right-hand side (RHS) of the rule.

Some applications of these rules are as follows:

- If “Fizzy Pop” appears on the RHS, the LHS can help us determine what the store should do to boost sales of this beverage.
- If “Bagels” appears on the LHS, the RHS can help us determine what products might be affected if the store no longer sells bagels.

The association rules generator part of this tool processes an input file, then generates an output file consisting of the rules. If X and Y are items in a record, then a rule such as

$$X \Rightarrow Y$$

indicates that whenever $X$ occurs in a record, expect $Y$ to occur with some frequency.

### Components of a Generated Association Rule

The strength of the association is quantified by three numbers. The first number, the *predictability* of the rule, quantifies how often *X* and *Y* occur together as a fraction of the number of records in which *X* occurs. For example, if the predictability is 50%, *X* and *Y* occur together in 50% of the records in which *X* occurs. Thus, knowing that *X* occurs in a record, expect that 50% of the time *Y* occurs in that record.

The second number, the *prevalence* of the rule, quantifies how often *X* and *Y* occur together in the file as a fraction of the total number of records. For example, if the prevalence is 1%, *X* and *Y* occur together in 1% of the total number of records.

You can specify a minimum prevalence threshold for the generated rules. The default minimum prevalence threshold is 1%. The lower the minimum prevalence, the more rules are generated, and the slower the performance of the tool might be. You can also specify a minimum predictability threshold for the generated rules. The minimum predictability threshold default is 50%.

Rules that meet a *minimum prevalence threshold* are important for two reasons:

1. A rule might have business value only if a reasonably significant fraction of records support the rule. For example, if everyone who buys caviar also buys vodka, the rule Caviar ⇒Vodka has 100% predictability. However, if only a handful of people buy caviar, the rule might be of limited value to the retailer.
2. A rule might not be statistically significant if a very small number of records support the rule. The rule might be due to chance, and it would not be prudent to make decisions based on such a rule.

The third number is *expected predictability*. The expected predictability is the frequency of occurrence of the RHS items. So the difference between expected predictability and predictability is a measure of the change in predictive power due to the presence of the LHS rule. Expected predictability gives an indication of what the predictability would be if there were no relationship between the items.

The Association Rules generator does not report rules in which the predictability is less than the expected predictability. In other words, a rule such as A->B is not reported if the frequency of A and B occurring together is less than the frequency of B alone.

**Note:** Given just Y and a rule of the form X ⇒ Y, nothing is known about X. Rules specify implications only from the LHS to the RHS.

Table 9-1 summarizes the three numbers that quantify the strength of each association rule.

**Table 9-1** Association Rules Components

| Measure | Description |
|---|---|
| Prevalence | Frequency of LHS and RHS occurring together. |
| Predictability | Fraction of RHS out of all items with LHS, or the prevalence divided by the frequency of occurrence of LHS items. |
| Expected Predictability | Frequency of occurrence of RHS items. |

### Hierarchical Data

The rules generator also works on hierarchical data, which includes a component that relates (or maps) data to new data at varying degrees of generality. The ability to handle hierarchical data allows rules to be generated at the desired level of generality.

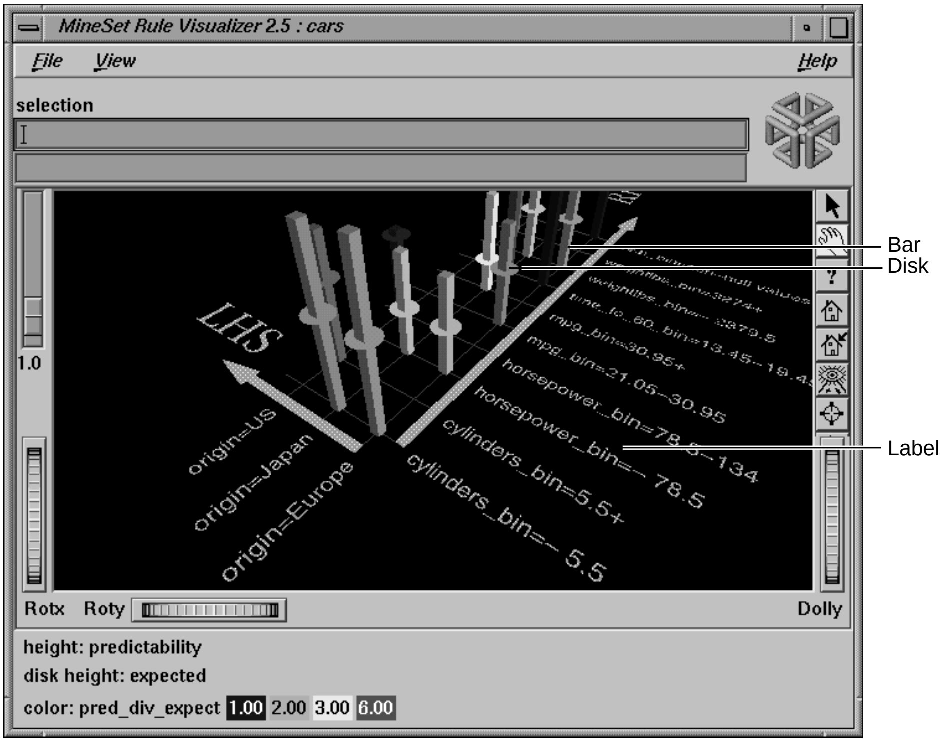
For example, consider the hierarchy shown in Table 9-2. This hierarchical information, in addition to the "market basket" data that lists the products purchased in each record, allows rules to be generated at four levels. In contrast to rules learned at the lowest level, which relate specific products to each other, a rule at the highest level might be "Milk implies Bread."

**Table 9-2** Example of Hierarchical Levels

| Level | Example |
|---|---|
| Product Group | Milk |
| Category | Non-Refrigerated Milk |
| Brand | Lucerne® |
| Product ID (UPC/SKU Code) | 1 pint can of Premium Condensed Milk |

## Rules Visualization

The rules visualization part lets you graphically display and explore the generated association rules. The rules are presented on a grid landscape, with left-hand side (LHS) items on one axis, and right-hand side (RHS) items on the other. As shown in Figure 9-2, attributes of a rule are displayed at the junction of its LHS and RHS item. The display can include bars, disks, and labels.



height: predictability

disk height: expected

color: pred_div_expect 1.00 2.00 3.00 6.00

**Figure 9-2** Detail View of the Rules Visualizer's Main Window

If the displayed view is too small, item labels do not appear on the side of the axes. You can zoom in on the view until the item labels appear (see the Dolly description in "Thumbwheels" in Chapter 6).

A legend indicating the mapping between displayed attributes (such as bar heights and colors) and the values associated with the underlying rules (such as predictability and prevalence) can be displayed at the bottom of the main window.

The Tool Manager interface for associations allows you to run the Rule Visualizer without running associations, by using the Visual Tools menu from Tool Manager's main window.

## File Requirements

Each of the Rules Visualizer's three components has its own file requirements. These are detailed in the following subsections.

### Files Required by the Association Data Converter Part

- A "raw" data file that results from extracting raw data from a source (such as a relational database). This file is processed by the association data converter to produce the internal binary data file used by the association rules generator.
- A format file that specifies the format of the data file. If the internal binary data file (see next subsection) is created via the Tool Manager, this format file is created automatically. If the internal binary data file is created via the command line, this format file must be created manually (see Appendix F, "Creating Data and Configuration Files for the Rules Visualizer").

### Files Required by the Association Rules Generator Part

- An internal binary data file, which results from running the association data converter on your original data.

  If you have hierarchical data, the association rules generator also requires the following two files:
- A mapping file, which specifies the mapping between hierarchical levels.
- A description file, which specifies a string description for each item at a specific hierarchical level.

### Files Required by the Rules Visualization Part

- A rules file that results from running the association rules generator.
- A *.ruleviz* configuration file that specifies parameters used by the rules visualizer program (such as mapping colors to prevalence values) when displaying the generated rules. This file is easily created using the Tool Manager (see Chapter 3). You also can use an editor (such as jot, vi, or Emacs) to produce this file (see Appendix F, "Creating Data and Configuration Files for the Rules Visualizer").

  These configuration files must have a *.ruleviz* extension.

## Starting the Rules Visualizer

The Rules Visualizer has three components. The following subsections describe the procedure for starting each one.

### Starting the Association Data Converter Part

There are two ways to start the association data converter part of the Rules Visualizer:

- Use the Tool Manager to configure and start the data converter. (See Chapter 3 first for details on most of the Tool Manager's functionality, which is common to all MineSet tools; see below for details about using the Tool Manager in conjunction with the data converter.)
- Enter the following command at the UNIX shell command-line prompt:

  **assoccvt** *parameters*

  The *parameters* are described in Appendix F, "Creating Data and Configuration Files for the Rules Visualizer."

### Starting the Association Rules Generator Part

There are two ways to start the association rules generator part of the Rules Visualizer:

- Use the Tool Manager to configure and start the association rules generator. (See Chapter 3 first for details on most of the Tool Manager's functionality, which is common to all MineSet tools; see below for details about using the Tool Manager in conjunction with the association rules generator.)
- If the data with which you are working is non-hierarchical, enter this command at the UNIX shell command line prompt:

  **assocgen** *parameters*

  If your data is hierarchical, enter this command at the UNIX shell command-line prompt:

  **mapassocgen** *parameters*

  The *parameters* for both instances are described in Appendix F, "Creating Data and Configuration Files for the Rules Visualizer."

### Starting the Rules Visualization Part

There are five ways to start the rules visualization part of this tool:

- Use the Tool Manager to configure and start the Rules Visualizer. (See Chapter 3 first for details on most of the Tool Manager's functionality, which is common to all MineSet tools; see below for details about using the Tool Manager in conjunction with the Rules Visualizer.)
- Double-click the Rules Visualizer icon, which is in the MineSet page of the icon catalog. The icon is labeled *ruleviz*. Since no configuration file is specified, the start-up screen requires you to select one by using File > Open.
- If you know what configuration file you want to use, double-click the icon for that configuration file. This starts the Rules Visualizer and automatically loads the configuration file you specified. This only works if the configuration filename ends in *.ruleviz* (which is always the case for configuration files created for the Rules Visualizer via the Tool Manager).
- Drag the configuration file icon onto the Rules Visualizer icon. This starts the Rules Visualizer and automatically loads the configuration file you specified. This works even if the configuration filename does not end in *.ruleviz*.
- Enter this command at the UNIX shell command-line prompt:

  ```
  ruleviz [ configFilename ]
  ```

When starting the rules visualization part of this tool, you must specify the configuration file, not the data or rules file.

### Option for Invoking the Rules Visualizer

The **`-quiet`** option eliminates the dialogs that popup to indicate progress. You can enable this option permanently by adding the line

```
*minesetQuiet:TRUE
```

to your *.Xdefaults* file.

## Configuring the Rules Visualizer Using the Tool Manager

This section describes how the components of the Rules Visualizer can be configured using the Tool Manager. Although the Tool Manager greatly simplifies the task of configuring the Rules Visualizer, you can construct a configuration file for this tool using an editor (see Appendix F, "Creating Data and Configuration Files for the Rules Visualizer").

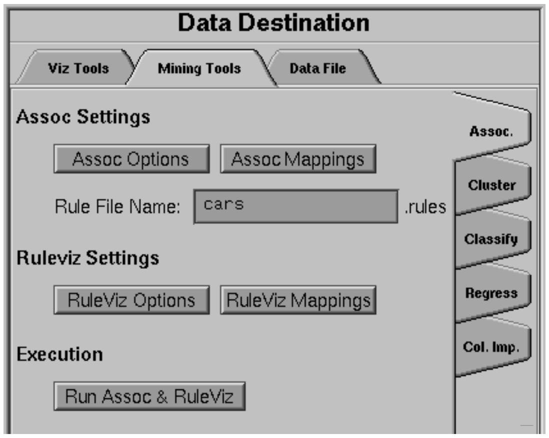
Note that the steps required to connect to a data source are described in Chapter 3.

The sections below follow the configuration and invocation of the Rules Visualizer components in the conventional order:

- creating a file for the association rules generator
- generating rules
- displaying rules

### Setting Up Associations

To show how to set up associations, the following example uses the *cars* database table. Assume that you want to find out if there is an association between miles per gallon, horsepower, and the year the car was built. For example, did mileage improve over time? Did engines become less powerful? The following steps (and Figure 9-3) show you how to set up the associations and map table columns to the data you want to study.



Rule File Name: cars .rules

**Figure 9-3** Initial Tool Manager Window for Association Generation

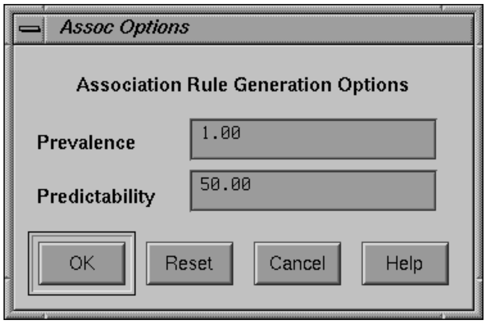
1. Connect to a MineSet server. Refer to Chapter 2, “Setting Up MineSet,”if you need help.
2. Open a data source.
3. (Optional step) In the Data Transformations tab you can choose the transformations you want do on the data before you give it to the associations engine. One recommended transformation is to create bins for numeric data. (The binning operation and the options available for it are described in detail in Chapter 3.) This leads to more “meaningful” rules from the association engine. For example, instead of using discrete values for the weightlbs attribute in the “cars” table such as 3504, 3693, 3436, 3433, and so on, it may be more meaningful to give weightlbs_bin value ranges such as 1600-2500, 2501-3500, and so on.

   For this example, click on the *Bin Columns* button, and select all the columns in the Bin Column window for binning.

   **Note:** If you run associations without binning any of the numerical columns (**int**s, **float**s, **double**s) you get the warning message
   ```
   Running associations on unbinned non-categorical data. Binning is
   recommended for producing more useful results.
   ```
4. Choose the Mining Tools tab from the Data Destination tab.
5. Choose the Assoc. tab (abbreviation for Associations) from the Mining Tools tab.

## Applying Association Rule Options

After selecting a data source, you can run the Association Rules generator. You can choose options for this by clicking on the *Assoc Options* button. This causes the dialog box in Figure 9-4 to be displayed.



Assoc Options

Association Rule Generation Options

Prevalence 1.00

Predictability 50.00

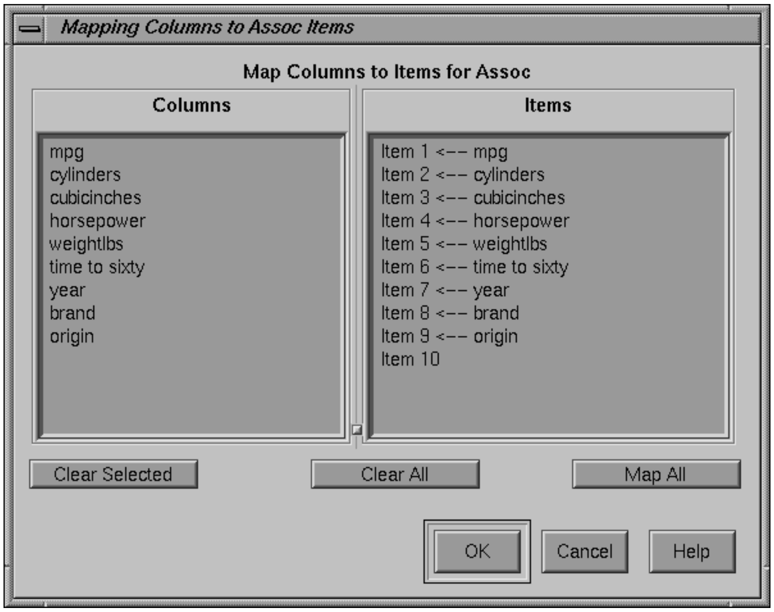
**Figure 9-4** Association Rule Options Dialog Box

**Prevalence—**lets you specify the minimum prevalence threshold as a percentage of the total number of records. Rules with a prevalence below this value are not generated. The default is 1%. The possible values are 0–100.

**Predictability—**lets you specify the minimum predictability threshold for rules. Rules with a predictability below this value are not generated. The default is 50%. The possible values are 0–100.

6. Once you have made your association rule options selections, click the *OK* button. This returns you to the Tool Manager startup screen.

## Mapping Columns to Association Items



Mapping Columns to Assoc Items

Map Columns to Items for Assoc

Columns

mpg
cylinders
cubicinches
horsepower
weightlbs
time to sixty
year
brand
origin

Items

Item 1 <-- mpg
Item 2 <-- cylinders
Item 3 <-- cubicinches
Item 4 <-- horsepower
Item 5 <-- weightlbs
Item 6 <-- time to sixty
Item 7 <-- year
Item 8 <-- brand
Item 9 <-- origin
Item 10

**Figure 9-5** Association Mappings Dialog Box

The database in the Current Columns text panel can contain multiple table columns. By mapping specific columns to association rules, the association rules generator can find the association between any possible pair of those items.

1. Click on *Assoc. Mappings* button to open the Mapping Columns to Assoc Items dialog box.

   The Mapping Columns to Assoc Items window shows two panels:

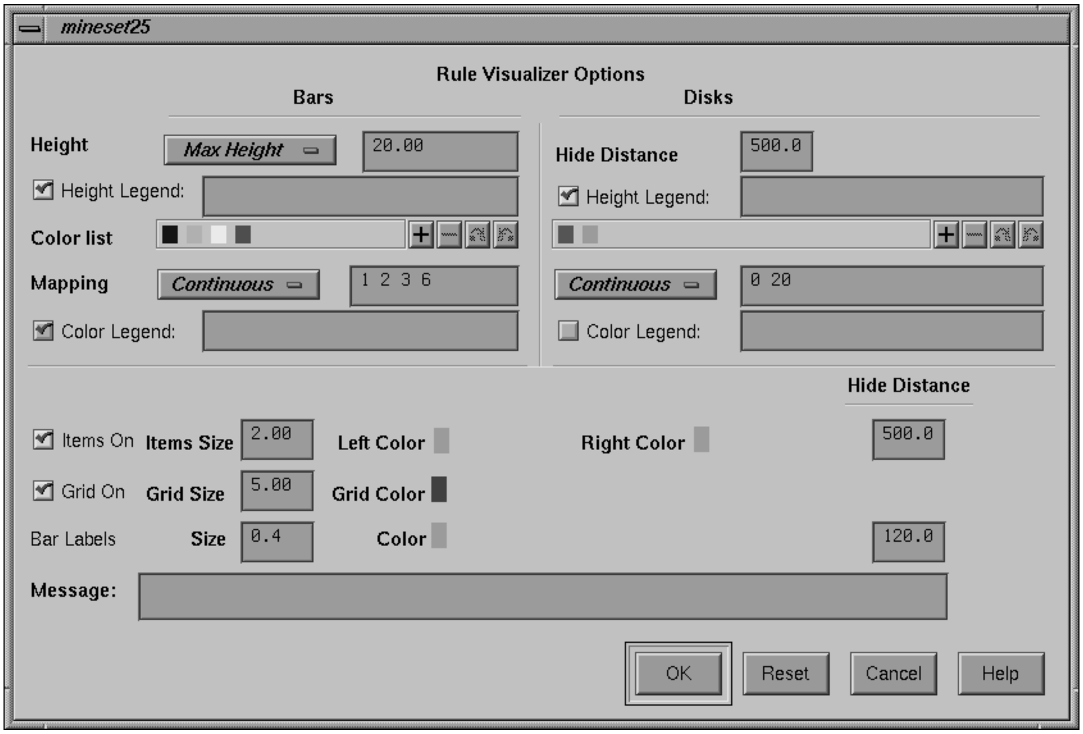
   - *Columns* shows the columns in the data
   - *Items* shows the mapping between columns in the data and items

   The *Map All* button on this window can be used to map all the attributes in the data source to items for the associations engine. The *Clear All* and *Clear Selected* buttons can be used to clear/change the mapping between columns and items.

2. The default behavior is to map all columns to items. Therefore, if you omit this step or if you open this window, you find all columns mapped. For this example, click *OK*.

## Specifying Ruleviz Options

Clicking on the *Ruleviz Options* button causes a new dialog box to be displayed (Figure 9-6). This lets you change some of the Rules Visualizer options from their default values.



Bars

Height: Max Height 20.00

☑ Height Legend:

Color list

Mapping: Continuous 1 2 3 6

☑ Color Legend:

Disks

Hide Distance: 500.0

☑ Height Legend:

Continuous 0 20

□ Color Legend:

Hide Distance

☑ Items On Items Size 2.00 Left Color Right Color 500.0

☑ Grid On Grid Size 5.00 Grid Color

Bar Labels Size 0.4 Color 120.0

Message:

**Figure 9-6** Rule Visualizer Options Dialog Box

This dialog box has two panels: the top one lets you set options for bars and disks; the bottom one lets you specify options for items, the grid, and labels.

Items in the top panel are listed below:

- *Height button*—lets you specify whether the bars and disk heights are to be normalized so that the tallest bar equals the height field value (*Max Height*), or whether they are to be scaled by the height field value (*Scale Height*).
- *Height field*—lets you enter the maximum or scale value for bar and disk heights.
- *Hide Distance*—lets you specify the distance at which disks are not graphically represented. Smaller numbers in this field specify a shorter distance; this means fewer disks are shown and performance is greater. Larger numbers indicate a greater distance; this means disks further away remain visible.
- *Legends*—lets you enter a text string that appears as mapping information displayed at the bottom of the main Rules Visualizer window. This is information about mapping between display entities and data values (for example, bar height corresponds to predictability values).
- *Color list*—lets you add or edit a color. To add a color to the list, click the + button. To edit a color, click the color. See “Choosing Colors” and “Using the Color Browser” in Chapter 3 for a more detailed explanation of how to choose and change colors.
- *Mapping*—lets you specify whether the color change that is shown in the graphic display is *Continuous* or *Discrete*. If you choose *Continuous*, the color values (of the bars or disks) shift gradually between the colors entered in the Color list field as a function of the values that are mapped to those colors in the Color list field.

**Example 9-1**

If you

- used the Color Browser to apply red and green (for bars and/or disks)
- selected *Discreet* for the *Mapping*
- entered the values `0 100`

then the display shows all bars and/or disks with values of less than 50 in red, and all those with values greater than or equal to 50 in green.

**Example 9-2**

If you

- used the Color Browser to apply red and green (for bars and/or disks)
- selected *Continuous* for the *Mapping*
- entered the values `0 100`

then the display shows all bars and/or disks with values less than or equal to 0 as completely red, those as greater than or equal to 100 as completely green, and those between 0 and 100 as shadings from red to green.

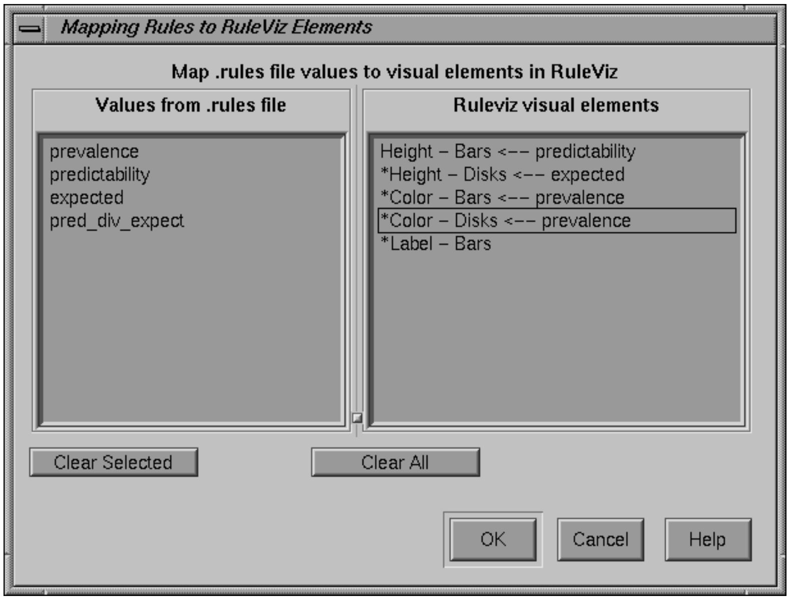
If no mapping and values are specified, a continuous mapping is used, and values are generated automatically from the minimum value to the maximum value in the data.

Items in the bottom panel are as follows:

- *Items On* and *Grids On* checkbox buttons let you determine whether items (the names on the side of the grid) are displayed or hidden.
- *Size* (for Items, Grid, and Bar Labels) lets you specify the size for items, the grid, and bar labels. If you mapped a column value to bar labels in the Requirements panel of the Tool Manager startup screen, you can specify a size for those labels.
- *Color* (for Left-Hand Items, Right-Hand Items, Grid, and Bar Labels) lets you specify the color for LHS and RHS items, the grid, and bar labels. If you mapped a column value to bar labels in the Requirements panel of the Tool Manager startup screen, you can specify a size for those labels.
- *Hide Distance* lets you specify the distance at which the LHS items, RHS items, grid, or labels become invisible. Smaller distances might improve performance, but the objects disappear more quickly. The higher the number, the greater the distance at which labels are hidden.
- *Message* lets you specify the message displayed when the pointer is moved over an object or when an object is selected. (See Figure 9-8.) The syntax of the message string is the same as for the mapviz message string. See the Message Statement section in Appendix C, “Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer.”

## Mapping Columns to Visual Elements

The Rules Visualizer lets you map attributes of the rules to visual elements of the display. Clicking on the *RuleViz Mappings* button brings up the *Ruleviz Mappings* panel shown in Figure 9-7.



Mapping Rules to RuleViz Elements
Map .rules file values to visual elements in RuleViz
Values from .rules file
Ruleviz visual elements
Clear Selected
Clear All
OK
Cancel
Help

prevalence
predictability
expected
pred_div_expect

Height – Bars <–– predictability
*Height – Disks <–– expected
*Color – Bars <–– prevalence
*Color – Disks <–– prevalence
*Label – Bars

**Figure 9-7** The Rules Visualizer's Mappings Panel

The visual elements that can be mapped are listed below, where the items with "*" are optional:

- *Height - Bars*—lets you specify what the bar heights represent.
- **Height - Disks*—lets you specify what the disk heights represent.
- **Color - Bars*—lets you specify what the bar colors represent.
- **Color - Disks*—lets you specify what the disk colors represent.
- **Label - Bars*—lets you specify what the bar labels represent.

The default mappings are as follows:

- *predictability* to bar heights
- *expected predictability* to *disk heights*
- *lift* to *bar and disk colors*

Lift is the predictability divided by the expected predictability.

### Invoking the Rules Visualizer

To see the Rules Visualizer graphically represent your data, click the *Run Assoc & Rules* button at the bottom of the Associations tab in the Data Destination panel of the main Tool Manager window.

## Working in the Rules Visualizer's Main Window

The Rules Visualizer part of this tool graphically displays the data in a rules file using the specifications of a valid configuration file. For example, specifying *group.ruleviz* results in the image shown in Figure 9-8.

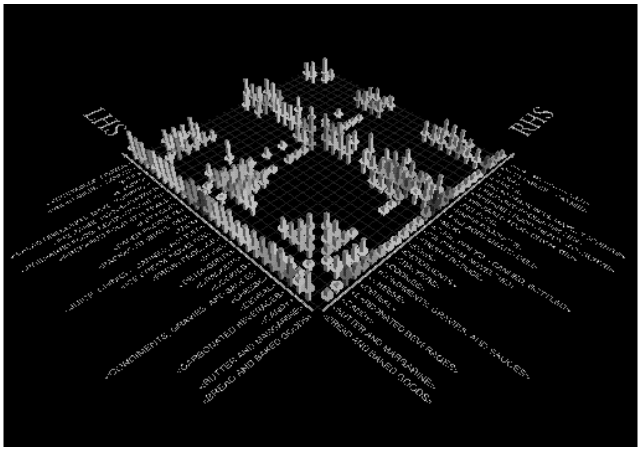


**Figure 9-8** Initial Rules Visualizer View When Specifying group.ruleviz

The rules are presented on a grid, initially displayed with left-hand side (LHS) items displayed on the left side of the window and right-hand side (RHS) items on the right. A rule is displayed at the junction of its LHS and RHS items. The display can include bars, disks, and labels.

When the scene is close enough, the LHS and RHS axes are labeled with the item names, unless this has been turned off in the configuration file. (To view the grid and rules at closer range, use the Dolly thumbwheel, described in the “Thumbwheels” in Chapter 6.)

You can change the labels as well as what the heights and colors of the bars and disks represent by modifying the configuration file via the Tool Manager (see Chapter 3) or using an editor to change the configuration file.

For example, in Figure 9-8, bar heights correspond to predictability values, bar colors correspond to prevalence values, and disk heights correspond to expected predictability.

## Viewing Modes

The two modes of viewing are *grasp* and *select*. To toggle between these modes, press the Esc key. You also can change from one mode to the other by clicking the appropriate button: to enter select mode, left-click the arrow button (to the top right of the main window); to enter *grasp* mode, left-click the hand button (immediately below the arrow button, near the top right of the main window as shown in Figure 9-2).

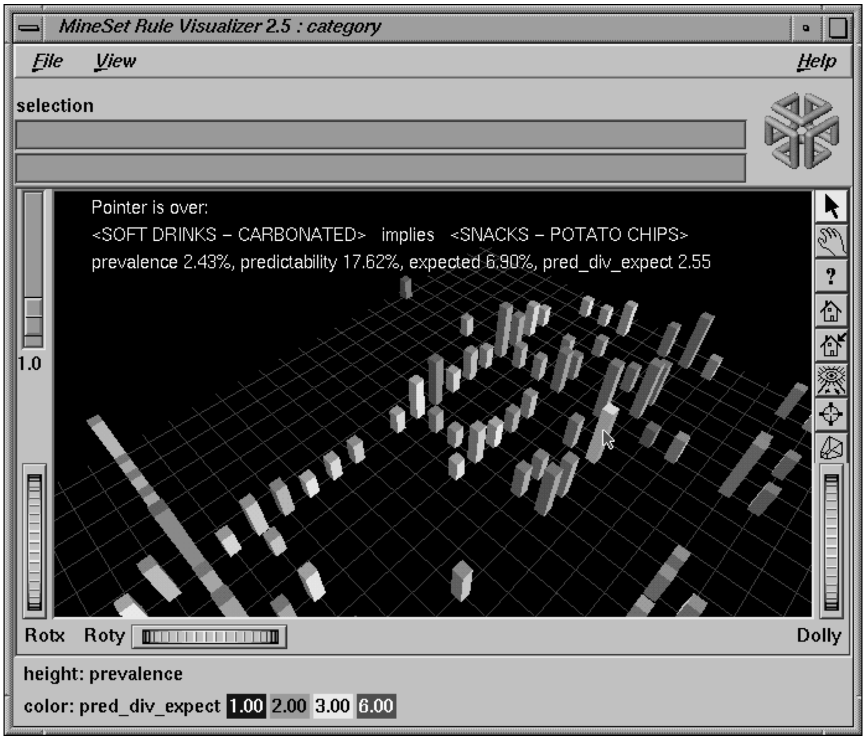
### Grasp Mode

In grasp mode the cursor appears as a hand. This mode supports panning, rotating, and scaling the scene’s size in the main window.

- To rotate the display, press the left mouse button and move the mouse in the direction you want to rotate. (Also see the rotating controls *Rotx* and *Roty* described in “Thumbwheels” in Chapter 6.)
- To pan the display, press the middle mouse button and drag it in the direction you want the display panned.
- To move the viewpoint forward, press the left and middle mouse buttons simultaneously and move the mouse downwards. To move the viewpoint backward, press the left and middle mouse buttons simultaneously and move the mouse upwards. This is equivalent to the functions provided by the Dolly thumbwheel.

### Select Mode

In select mode, you can obtain additional information about a rule by placing the cursor over a bar. This highlights the selected bar and causes information about the rule represented by that bar to appear at the top of the main window.



Pointer is over:
<SOFT DRINKS – CARBONATED> implies <SNACKS – POTATO CHIPS>
prevalence 2.43%, predictability 17.62%, expected 6.90%, pred_div_expect 2.55

height: prevalence
color: pred_div_expect 1.00 2.00 3.00 6.00

**Figure 9-9** Cursor Over a Rules Visualizer Object

The information is displayed as long as the cursor remains over the object. If you position the pointer cursor over an object and click the left mouse button, that same information appears in the Selection Window, which is above the main window, under the "Selection" label.

This Selection information remains visible until another object is selected, or until no object is selected (if you click the black background). Using the mouse, you can cut and paste this text into other applications, such as reports or databases.)

## External Controls

Several external controls surround the main window, including buttons and thumbwheels. (These and the rest of the buttons are the same as the other MineSet visualization tools and are described in “Buttons” in Chapter 6, and “Thumbwheels” in Chapter 6)

### The Height Slider

The *Height* slider, at the upper left corner of the main window, lets you scale the heights of objects (bars and disks) in the main window.

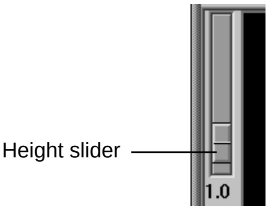


**Figure 9-10** Rules Visualizer’s Height Slider

# Pulldown Menus

The Rules Visualizer has three pulldown menus, labeled File, View, and Help.

## The File Menu

The File menu (Figure 9-11) contains six options.

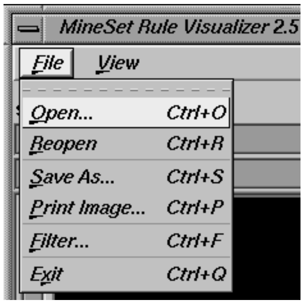


**Figure 9-11** Rules Visualizer File Menu

- *Open* loads and opens a configuration file, displaying it in the main window. Previously displayed data is discarded.
- *Reopen* reloads the current configuration file. This is useful if either the configuration file or data file has changed.
- *Save As*... allows uyou to save the file under a different file name
- *Print Image*... allows you to print the image from the screen
- *Filter*....allows you to filter the data.
- *Exit* closes the current window and exits the application.

## The Filter Menu

The Filter menu brings up a Filter panel (Figure 9-12) that lets you reduce the number of rules displayed in the main viewing area, based on one or more criteria. You can use the filter panel to fine-tune the display, emphasize specific information, or simply shrink the amount of information displayed.

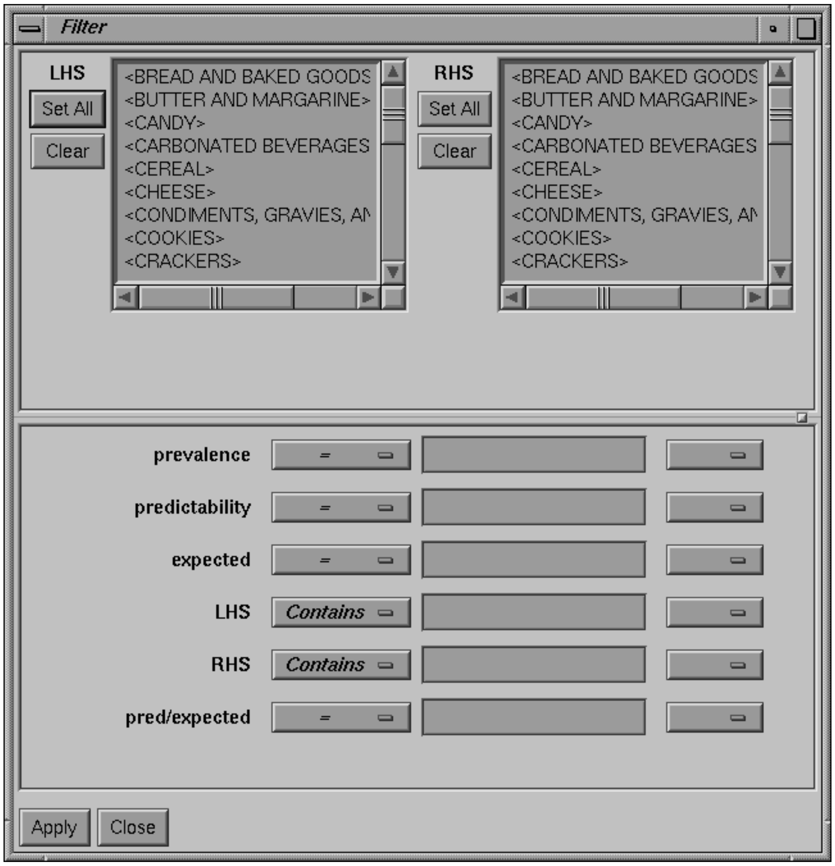


**Figure 9-12** Rules Visualizer Filter Panel

The top pane lets you filter based on string variables, such as LHS and RHS. To select all values of a variable, click *Set All*. To clear the current selections, click *Clear*. To select a value, click it. To deselect a value, click it again.

The bottom pane lets you filter based on the values of both string and numeric variables.

To filter numeric values, enter the value, and select a relational operation (=, !=, >, <, >=, <=). To filter alphanumeric values, enter the string. You can use any of three types of string comparisons:

- Contains indicates that it contains the appropriate string. For example, California contains the strings Cal and forn.
- Equals requires the strings to match exactly.
- Matches allows wildcards:
  - An asterisk (*) represents any number of characters.
  - A question mark (?) represents one character.
  - Square braces ([ ]) enclose a list of characters to match.

  For example, California matches Cal*, Cal?fornia, and Cal[a-z]fornia.

In addition to numeric and string comparison operations, you can specify `Is Null.` Currently, this option does not match any rules, resulting in an empty display.

To the right of each field is an additional option menu that lets you specify “And” or “Or” options. For example, you could specify “sales > 20 And < 40.” You can have any number of And or Or clauses for a given variable, but cannot mix And and Or in a single variable.

Click the *Filter* button to start filtering. If you press *Enter* while the panel is active, filtering starts automatically.

Click the *Close* button to close the panel.

### The View Menu

The View menu (Figure 9-13)contains one option.

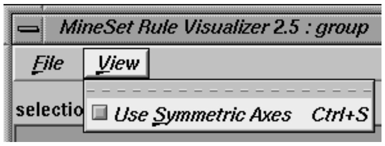

MineSet Rule Visualizer 2.5 : group
File
View
selectio
Use Symmetric Axes Ctrl+S

**Figure 9-13** Rules Visualizer View Menu

Use Symmetric Axes controls how items are displayed along the left- and right-hand side axes. If enabled, every item appears on both axes, making the axes identical. Otherwise, only the required items appear on each axis.

### The Help Menu

The Help menu is the same for all MineSet Visualization tools, (see “The Help Menu” in Chapter 5 for a complete description).

## Sample Files

The provided sample data, rules, and configuration files demonstrate the features and capabilities of the Rules Visualizer.

### Sample Files for the Association Data Converter

There are two sample files provided for each of the two formats of the association data converter. These files are located in the */usr/lib/MineSet/assoccvt/examples* directory.

- *sing.dat* and *sing.fmt*
  The *sing.dat* file is a “raw” data file type, as described in the “Files Required by the Association Data Converter Part” on page 294. The *sing.fmt* file is the format file described in the same section. Both files are of the single-item-per-record format.
- *mult.dat* and *mult.fmt*
  The *mult.dat* file is a “raw” data file type, as described in the “Files Required by the Association Data Converter Part” on page 294. The *mult.fmt* file is the format file described in the same section. Both files are of the multiple-item-per-record format.

## Sample Files for the Association Rules Generator

These files are located in the */usr/lib/MineSet/assocgen/examples* directory. Except for the *synthn.dsc* file, the sample files for the association rules generator are provided in 2-byte and 4-byte integer versions. The difference between the respective files is that the 4-byte integer version requires twice the amount of storage space of the 2-byte integer version.

- **synthn.dsc**
  This is a description file for items at the *n*th level of the hierarchy. For example, if n is 0, this file describes the lowest level; if n = 1, the file describes the next higher level of the hierarchy, and so forth. Description files are common to both 2-byte and 4-byte integer files.

### Two-byte Integer Version

- *synths.dat*
  This is a data file with 2-byte integers. It corresponds to the data shown in Table F-9 on page 658.
- *synths.map*
  This is a 2-byte integer mapping file for hierarchical data.

### Four-byte Integer Version

- *synthb.dat*
  This is a data file with 4-byte integers. It corresponds to the data shown in Table F-9 on page 658.
- *synthb.map*
  This is a 4-byte integer mapping file for hierarchical data.

## Sample Files for the Rules Visualization Part

The following sample rules and configuration files are provided for use with the rules visualization part of this tool. These files correspond to the hierarchical datasets. Rules files contain the generated rules obtained by running the association rules generator part of the Rules Visualizer. Rules files must have a *.rules* extension. Each configuration file specifies how the corresponding rules file is displayed. Configuration files must have a *.ruleviz* extension. The files mentioned in this subsection are in the */usr/lib/MineSet/ruleviz/examples* directory.

- *group.rules* and *group.ruleviz*

  These files provide the generated rules and configuration specifications for product groups, such as bread and baked goods, dairy milk, and carbonated beverages.

- *category.rules* and *category.ruleviz*

  These files provide the generated rules and configuration specifications for product categories within product groups, such as refrigerated or non-refrigerated milk.

- *people94.rules* and *people94.ruleviz*

  These files provide the generated rules and configuration specifications for a census database, showing associations among marital status, education level, age, income, and other variables.

- *germanCredit.rules* and *germanCredit.ruleviz*

  These files provide the generated rules and configuration specifications for a credit database from Germany, showing associations among credit history, employment, savings, and other variables.

See */usr/lib/MineSet/ruleviz/examples/README* for additional information on the files in that directory.

*Chapter 10*

# MineSet Inducers and Classifiers

This chapter provides an introduction to classifiers and the algorithms that build them, called inducers. MineSet provides three inducer-classifier pairs:

- Decision Tree
- Option Tree
- Evidence

The information in this chapter is equally applicable to all the MineSet classifiers and inducers. The chapter consists of two parts: the first part introduces the basic concepts, and the second part details how to apply those concepts via the Tool Manager.

Detailed descriptions of the MineSet inducers and classifiers are provided in Chapter 11, “Inducing and Visualizing the Decision Tree Classifier,” Chapter 12, “Inducing and Visualizing the Option Tree Classifier,” and Chapter 13, “Inducing and Visualizing the Evidence Classifier.”

## Classifiers

A *classifier* predicts one attribute of a set of data, given several other attributes. For example, if you have data on customers of a telecommunications company, a classifier can be generated to predict whether the customer will churn (leave the company) given information such as whether the customer has voice mail, an international plan or not, and how much time they spend on the phone. The attribute being predicted is called the label, and the attributes used for prediction are called the descriptive attributes.

MineSet can build a classifier automatically from a training set. The training set consists of records in the data for which the label has been supplied. For example, you supply a database table with one column for each descriptive attribute (such as the presence of a voice mail plan, the average number of calling minutes per day), and one column for the label (churned or not). An algorithm that automatically builds a classifier from a training set is called an inducer.

When a classifier is generated, MineSet also generates a visualization that can help you understand how the classifier operates. This visualization can also provide valuable insight into the data itself. Once a classifier is generated, it can be used to classify records that do not contain the label attribute. This value is predicted by the classifier.

**Note:** See Appendix K for a list of further readings about classifiers as well as acknowledgements for the datasets used in MineSet sample files.

## Decision Tree Classifiers

Figure 10-1 shows the Decision Tree generated by the Decision Tree Inducer for the churn dataset.

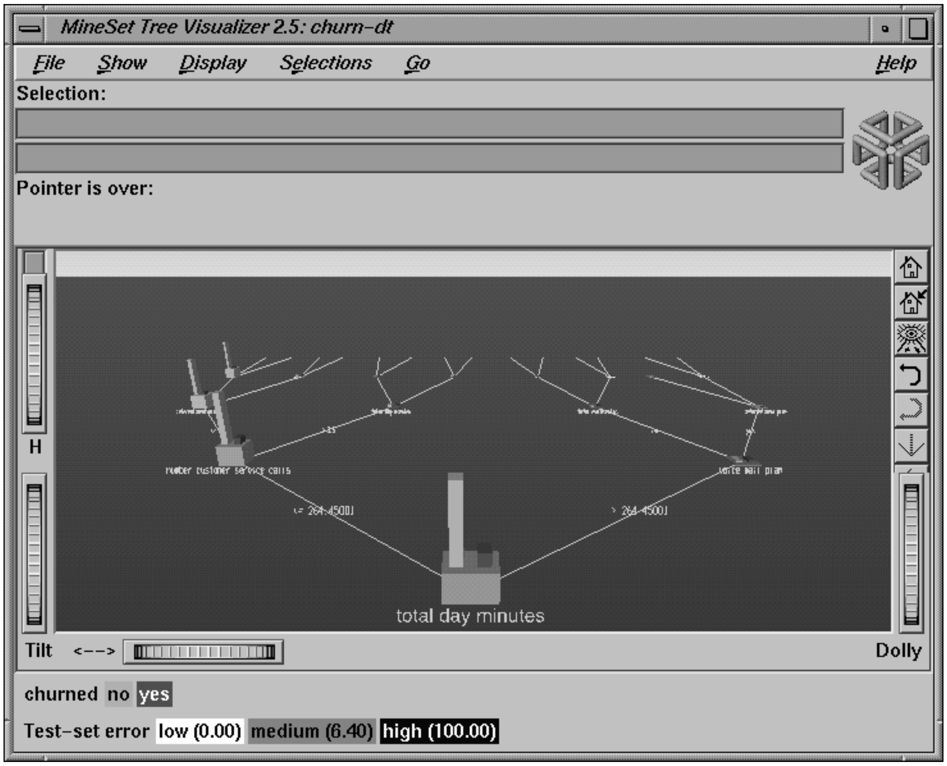


**Figure 10-1** The Decision Tree Generated by the Decision Tree Inducer for Churn Dataset

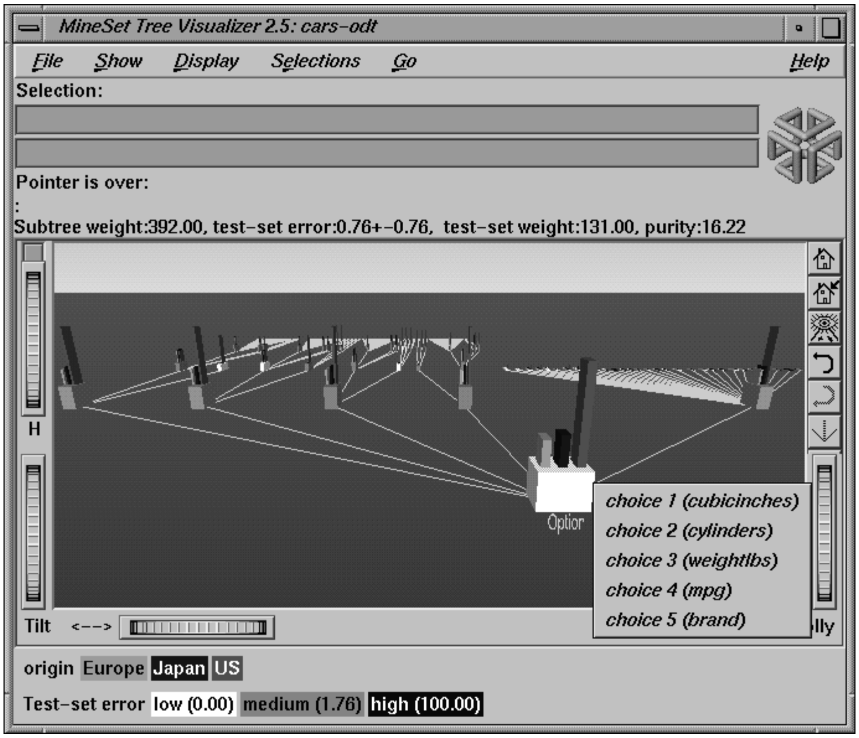
To understand how the Decision Tree classifier assigns a label to each record, look at the attributes tested at the nodes and the values on the connecting lines. In the Decision Tree shown in Figure 10-1, the first test (at the root of the tree) is for total day minutes. There are two branches from this root. If the total day minutes is <= 264.45, the left branch is taken; otherwise the right branch is taken. The process is repeated until a leaf (node with no branches) is reached. The leaf is labeled with the predicted class. The leaf represents a rule that is the conjunction of all tests from the root to the leaf. For example, the right most leaf, labeled No, matches the rule

total day minutes > 264.45 and voice mail plan = yes and

international plan = yes and total day minutes > 276.3

## Option Tree Classifiers

Figure 10-2 shows an Option Tree generated by the Option Tree inducer.



Subtree weight:392.00, test-set error:0.76+-0.76, test-set weight:131.00, purity:16.22

**Figure 10-2** The Option Tree Generated by the Option Tree Inducer for the Cars Dataset

The top node in this figure is an “Option node,” which indicates that several good attributes can be chosen at the root. A Decision Tree Inducer picks the single “best” attribute for each subtree; however, there might be several good attributes on which to split. In such cases, an Option Tree can create option nodes. In the example dataset (Figure 10-2), the task is to predict whether a car is manufactured in Europe, Japan, or the US. The Decision Tree Inducer picks cubic inches for the root. The Option Tree inducer chooses several options: cubic inches, cylinders, weight, mpg, and brand are all good choices for the root.

Option nodes can appear elsewhere besides the root. With the default settings, however, they appear only at the root or one level below the root (after a single test node).

Option Trees usually take 10 to 15 times longer to build than do Decision trees, but they provide two significant advantages:

1. Comprehensibility — Option nodes let you see several likely options. Instead of having to settle for a single attribute, option nodes let you choose from several. When you fly over the tree, you can choose to follow an option that you believe is easier to understand or that you believe is better for predictions based on your background knowledge of the problem.
2. Accuracy — In many cases, Option Trees are more accurate (have lower error-rates) than Decision Trees. Option Trees classify by letting each option “vote” for each label value, then average the votes. This is similar to having a series of “experts,” each one attempting to predict the label based on a different main criterion. The option node averages all these experts’ votes. Just as distributing stock investments reduces the risk, using a mixture of options usually results in a more stable, less risky classifier.

## Evidence Classifiers

Figure 10-3 shows the evidence information generated by the Evidence Inducer.

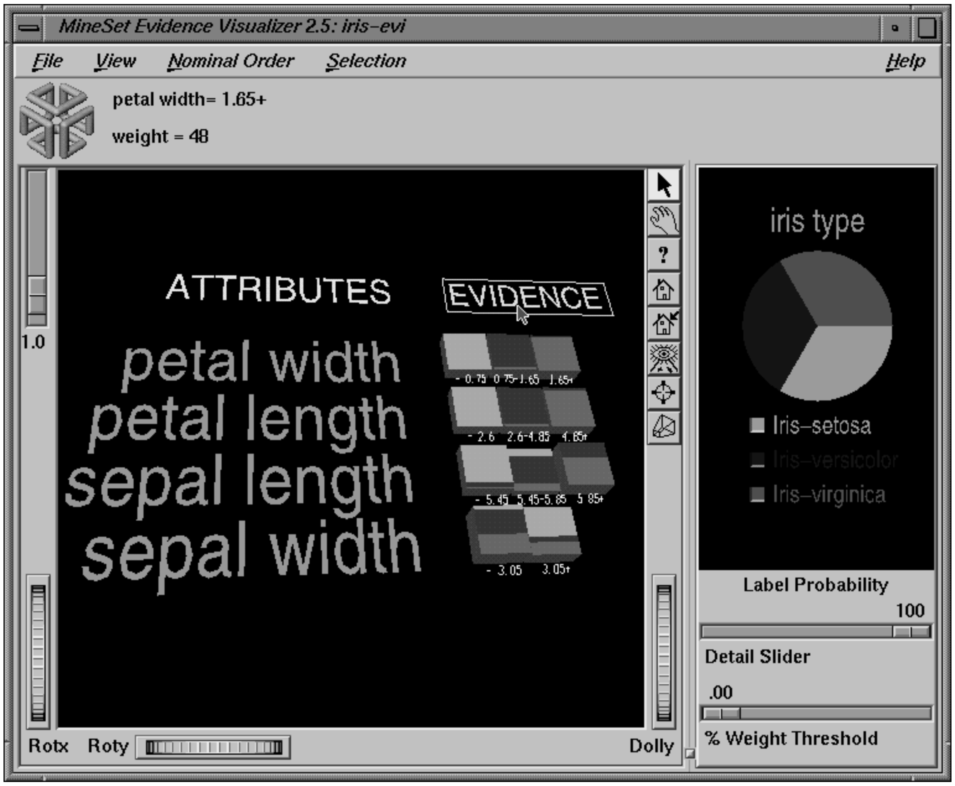


**Figure 10-3** Results of Evidence Inducer for Iris Dataset

The right window of the screen shows the distribution of the classes in the training set. The left side shows rows of cake charts, one for each attribute. For every value of an attribute in the data, there is one chart matching it in the row for the attribute. Given a record with an attribute value corresponding to a chart, the chart represents how much evidence the classifier "adds" to each possible label value. For example, in Figure 11-3, a record with total day minutes < 175 shows much evidence for the No label value, and little evidence for the Yes label value. After evidence is accumulated from all the attributes, the label value with the most evidence is predicted.

## Inducers

An inducer is an algorithm that builds a classifier from a *training set*, which consists of records with labels. The training set is used by the inducer to "learn" how to construct the classifier, as shown in Figure 10-4.

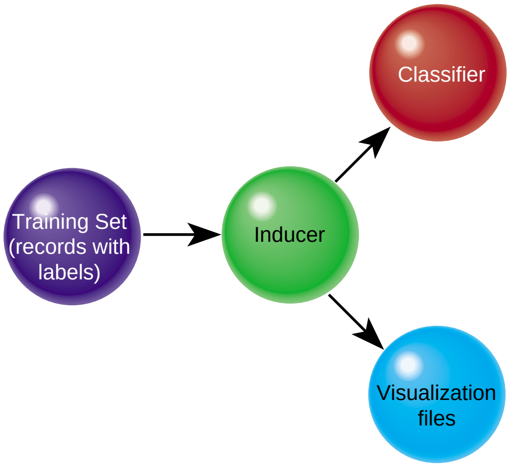


**Figure 10-4** Method for Building a Classifier

Once the classifier is built, its structure can be visualized or used to classify unlabeled records, as shown in Figure 10-4 and Figure 10-5.

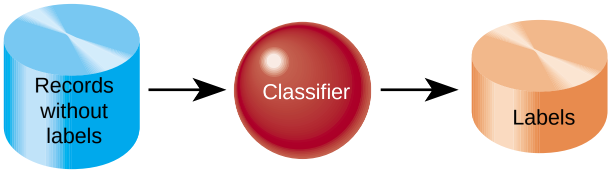


**Figure 10-5** Using a Classifier to Label New Records

Running inducers can be a CPU- and I/O-intensive process. For this reason, the MineSet inducers run on the MineSet server, rather than on the MineSet client (see Figure 10-6).

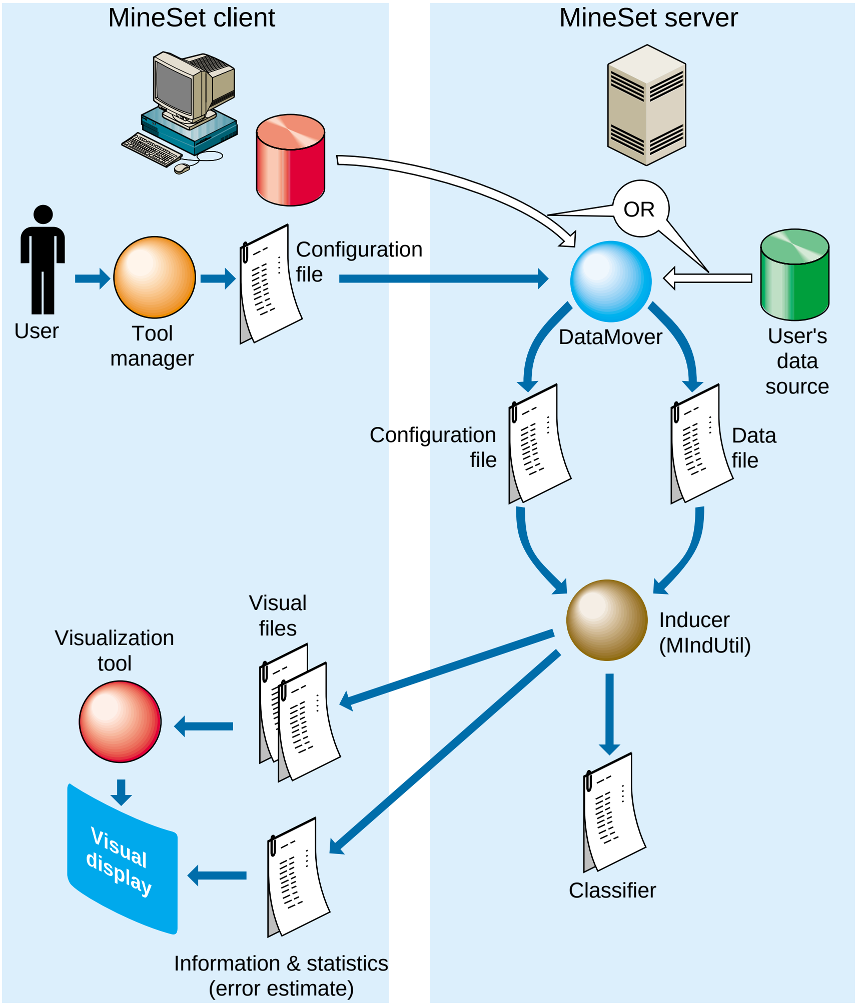


**Figure 10-6** Tool Execution Sequence for Classifiers

## Training Set

Inducers require a training set, which is a table containing attributes, one of which is designated as the class label. The label attribute type must be discrete (binned values, character string values, or a few integers). The number of possible values for the label attribute should be small, preferably two or three values. Let's look at an example where the goal is to classify the type of an iris flower (iris-setosa, iris-versicolor, or iris-virginica) given as descriptive attributes its sepal length, sepal width, petal length and petal width. Figure 10-7 shows several records from a sample training set for this problem.

| | **Descriptive Attributes** | | | | **Label** |
|---|---|---|---|---|---|
| | sepal length | sepal width | petal length | petal width | iris type |
| Record 1 | 5.1 | 3.5 | 1.4 | 0.2 | Iris-setosa |
| Record 2 | 5.9 | 3 | 5.1 | 1.8 | Iris-virginica |
| Record 3 | 6.5 | 2.8 | 4.6 | 1.5 | Iris-versicolor |
| ⋮ | 6.3 | 2.9 | 5.6 | 1.8 | Iris-virginica |
| | 6.5 | 3 | 5.8 | 2.2 | Iris-virginica |

**Figure 10-7** Sample Records From a Training Set

Once a classifier is built, it can classify new records as belonging to one of the above classes (see Figure 10-5). These new records must be in a table that has all the attributes used by the classifier with the same name and type as they were in the training set. The table need not contain the label attribute. If it exists, it is ignored during classification.

### Applying a Model

After building a classifier, you can apply it to records to predict their label. For example, if you built a classifier for predicting iris type, you can apply the classifier to records containing only the descriptive attributes, and a new column is added with the predicted iris type.

In a marketing campaign, for example, a training set can be generated by running the campaign at one city and generating label values according to the responses in that city. A classifier can then be induced and campaign mail can then be sent only to people who are labeled by the classifier as likely to respond, thus saving mailing costs.

As an example of using mining tools for ensuring data quality, after building a classifier you can apply it to the training set in order to identify records that are mislabeled by the classifier. Such records might warrant closer investigation. Perhaps they are "noise," or they might yield special insights. If, for example, you have a Decision Tree for the iris dataset induced using the *Classify Only* mode, by applying the classifier, you get a new column (iris type_1) containing the predicted labels. You can then add a column that is defined as type **int** with the expression (iris type != iris type_1). The new column has a 1 whenever the classifier misclassifies, and a zero when it correctly classifies. Figure 10-8 shows a Scatter Visualizer plot of the data where the new column is mapped to color with the colors set such that green is 0 (OK) and 1 is red (error). By looking at the plot, it is possible to determine where mistakes are being made.

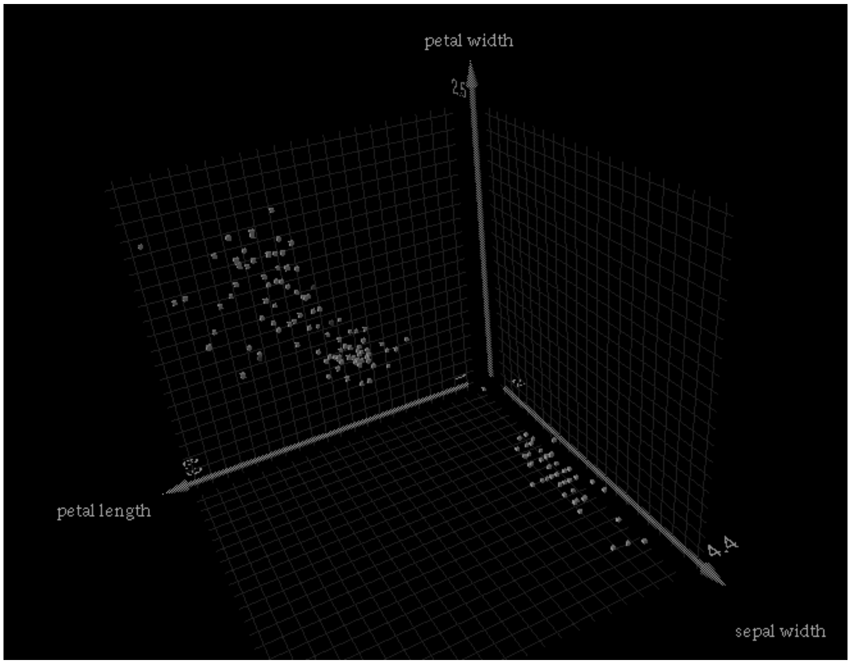


**Figure 10-8** Iris Dataset Misclassification, Example 1

Another alternative is to define the new column as a float with the expression (iris type != iris type_1) + 0.01. The Scatter Visualizer can then be used with the original label mapped to color, and this new column mapped to size. Incorrect predictions are shown as big cubes; correct predictions are shown as small cubes (see Figure 10-9).

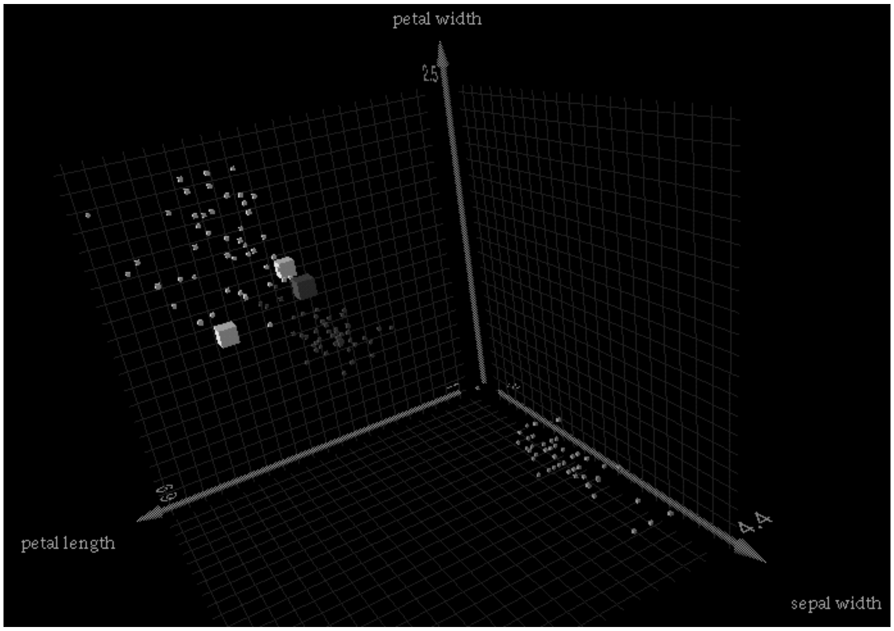


**Figure 10-9** Iris Dataset Misclassification, Example 2

## Error Estimation

When a classifier is built, it is useful to know how well you can expect it to perform in the future (what is the classifier's error-rate). Factors affecting classification error-rate include:

- The number of records available in the training set.

  Since the inducer must learn from the training set, the larger the training set, the more reliable the classifier should be; however, the larger the training set, the longer it takes the inducer to build a classifier. The improvement to the error-rate decreases as the size of the training set increases (this is a case of diminishing returns).

- The number of attributes.

  More attributes mean more combinations for the inducer to compute, making the problem more difficult for the inducer and requiring more time. Note that sometimes random correlations can lead the inducer astray; consequently, it might build less accurate classifiers (technically, this is known as "overfitting"). If an attribute is irrelevant to the task, remove it from the training set (this can be done using the Tool Manager).

- The information in the attributes.

  Sometimes there is not enough information in the attributes to correctly predict the label with a low error-rate (for example, trying to determine someone's salary based on their eye color). Adding other attributes (such as profession, hours per week, and age) might reduce the error-rate.

- The distribution of future unlabeled records.

  If future records come from a distribution different from that of the training set, the error-rate probably will be high. For example, if you build a classifier from a training set containing family cars, it might not be useful when attempting to classify records containing many sport cars, because the distribution of attribute values might be very different.

The two common methods for estimating the error-rate of a classifier are described below. Both of these assume that future records will be sampled from the same distribution as the training set.

- Holdout: A portion of the records (commonly two-thirds) is used as the training set, while the rest is kept as a *test set*. The inducer is shown only two-thirds of the data and builds a classifier. The test set is then classified using the induced classifier, and the error-rate or loss on this test set is the estimated error-rate or estimated loss. Figure 10-10 shows this error estimation method.

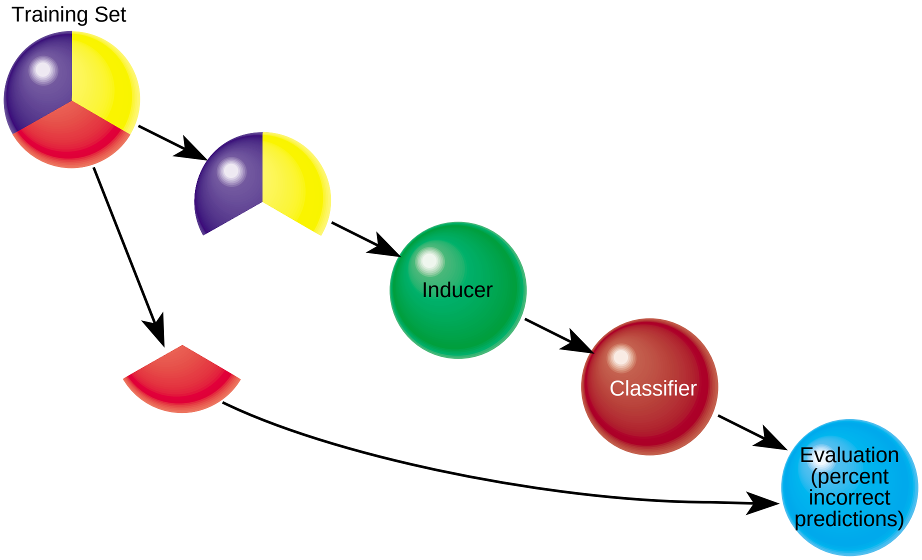


**Figure 10-10** Estimating the Classifier's Accuracy

This method is fast, but since it uses only two-thirds of the data for building the classifier, it does not make efficient use of the data for learning. If all the data were used, it is possible that a more accurate classifier could be built.

- Cross-validation: The data is split into *k* mutually exclusive subsets (*folds*) of approximately equal size. The inducer is trained and tested *k* times; each time, it is trained on all the data minus a different fold, then tested on that holdout fold. The estimated error-rate is then the average of the errors obtained. Figure 10-11 shows cross-validation with *k*=3 (note that the default value is *k*=10).

  Cross-validation can be repeated multiple times (*t*). For a *t* times *k*-fold cross-validation, *k**t* classifiers are built and evaluated. This means the time for cross-validation is *k**t* times longer. By default, *k*=10 and *t*=1, so cross-validation takes approximately 10 times longer than building a single classifier.

  Increasing the number of repetitions (*t)* increases the running time and improves the error estimate and the corresponding confidence interval.

  You can increase or decrease *k*. Reducing it to 3 or 5 shortens the running time; however, estimates are likely to be biased pessimistically because of the smaller training set sizes. You can increase *k*, but this is recommended only for very small datasets.

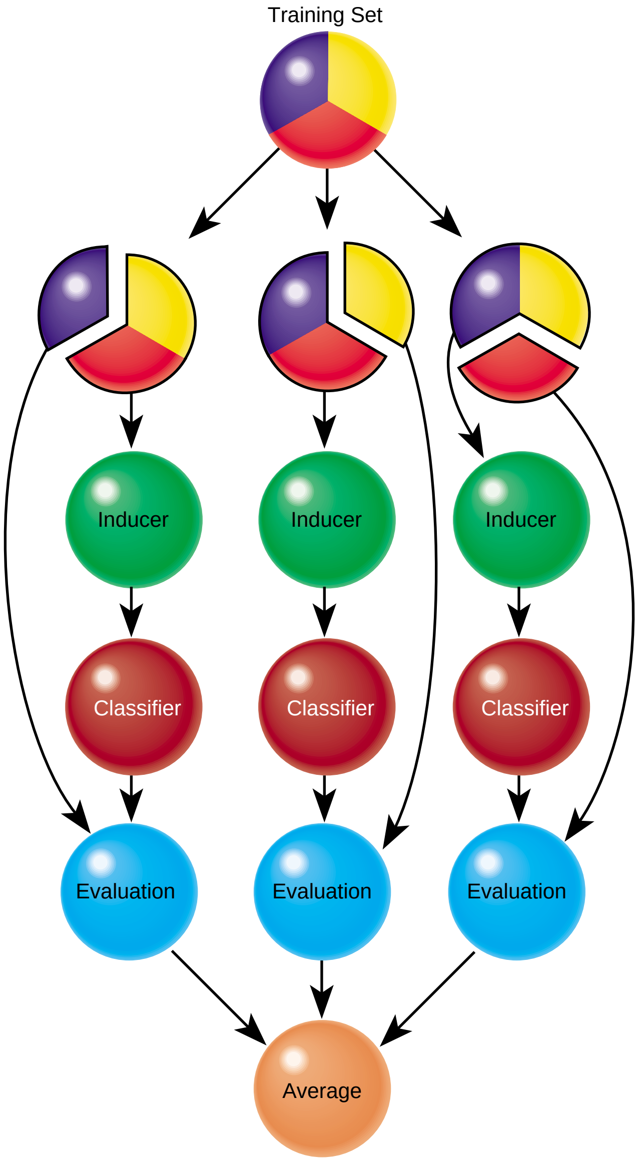


**Figure 10-11** Classifier Cross-Validation (k=3)

Generally, a holdout estimate should be used at the exploratory stage, as well as on datasets of over 5,000 records. Cross-validation should be used for the final classifier building phase, as well as on small datasets.

## Backfitting in Error Estimation

An inducer builds a classifier, which has two parts:

- Structure — For Decision Trees and Option Trees, the structure is the shape of the tree. For evidence, the structure is the number of bins for every attribute and the thresholds if the attribute is numeric.
- Probability estimates — Each part of the structure estimates the probability of each class. These estimates are commonly based on the counts of training records at different points in the structure. For Decision Trees, the probabilities are determined by the weight of records at the leaves. For the Evidence classifier, the probabilities are determined by the conditional probabilities for every attribute value or range.

Backfitting a classifier with a set of records does not alter the structure of the classifier, but updates the probability estimates based on the given data. Backfitting is useful for several reasons:

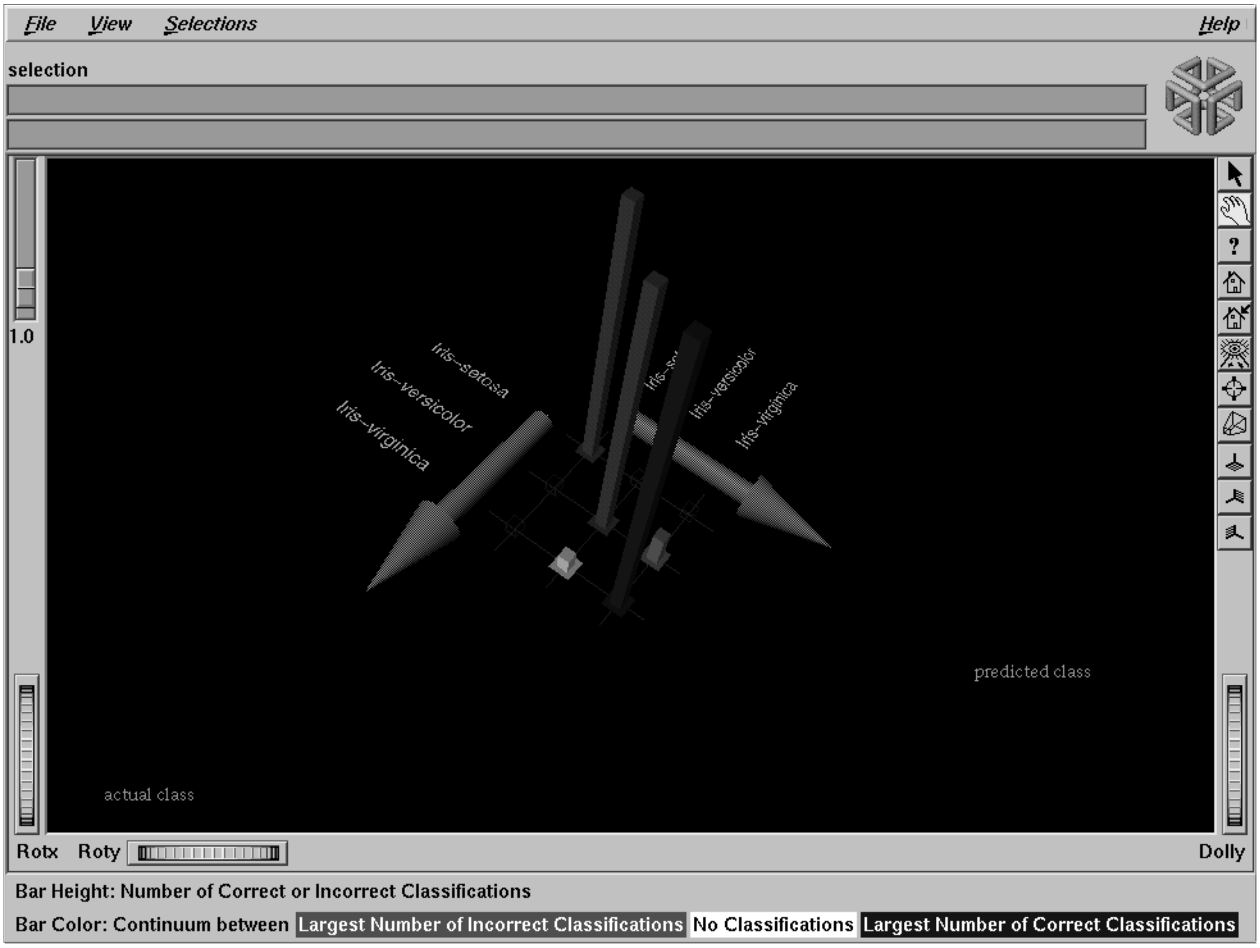
1. A structure can be built from a small training set, then backfitted with a big dataset to improve the probability estimates in the structure. Backfitting is a faster process than inducing the classifier's structure.
2. When holdout error estimation is used, a portion of the data is left out for testing. Once the classifier structure is induced and the error estimated, it is possible to backfit all of the data through the structure, which can reduce the error of the final classifier. When counts, weights, and probabilities are shown in the classifier's structure, they reflect all the data, not just the training set portion.

When using drill-through from the visualizers, you can see data corresponding to the weights shown, which reflect the whole dataset. If backfitting is not used, the weights shown represent only the training set.

## Confusion Matrices in Error Estimation

Confusion matrices give a more detailed picture of the errors made by a classifier. Instead of simply analyzing the number of correct and incorrect predictions, the confusion matrix shows the *type* of errors being made.

Figure 10-12 shows a confusion matrix for a Decision Tree that was induced on the iris dataset.



Bar Height: Number of Correct or Incorrect Classifications

Bar Color: Continuum between Largest Number of Incorrect Classifications No Classifications Largest Number of Correct Classifications

**Figure 10-12** Confusion Matrix for Iris Dataset

The two axes represent:

- the class values predicted by the classifier, and
- the actual class values given in the test set (holdout set).

Entries on the diagonal are correct predictions. Entries off the diagonal indicate incorrect predictions. This representation shows that *iris-versicolor* and *iris-virginica* are frequently confused, but *iris-setosa* is always predicted correctly.

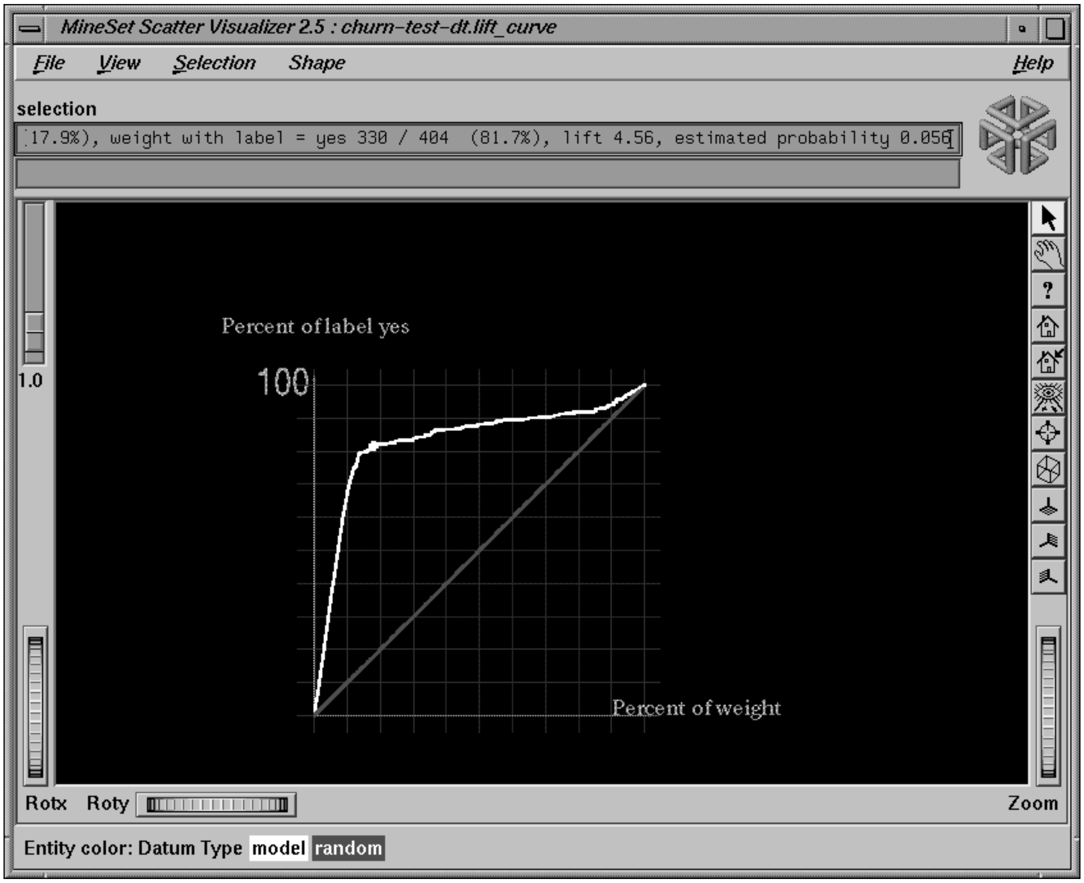
When the cost of making different types of mistakes is uneven, it is frequently useful to understand the type of errors that are being made (see loss matrices below).

**Note:** The confusion matrix shows the errors made on the test set; thus, it represents the expected true distribution of errors in an actual situation if the underlying distribution of the data does not change significantly. The confusion matrix in MineSet is computed prior to backfitting and is the same whether or not backfitting is applied.

## Lift Curves in Error Estimation

A lift curve is a graph that plots the cumulative weight of the records from a specified label value as a function of the weight of all the records. The order in which the records occur determines the slope of the curve. Typically, a lift curve plots the difference between randomly ordered records and records sorted based on a classifier's predictions.

For example, in telecommunications, it is valuable to be able to predict which customers are likely to switch providers (churn). In the dataset *churn*, about 13.5% of the customers are likely to switch provider. Figure 10-13 shows the lift curve obtained by using a Decision Tree classifier on this dataset.



```
17.9%), weight with label = yes 330 / 404  (81.7%), lift 4.56, estimated probability 0.056
```

**Figure 10-13** Lift Curve for the Churn Dataset

The X axis shows the number of records sampled; the Y axis shows the number of records corresponding to customers who churn. The lower curve (red) shows the number of customers expected to churn given a random ordering of the records. The upper curve (white) shows the percentage of customers that churn when ordered according to the classifier's score (probability estimate) for each record. Records representing customers that the classifier identifies as most likely to churn appear first; those less likely to churn appear last. The lift that the classifier ordering provides can be seen by the difference between the classifier curve and the random curve.

If some action should be taken before customers churn, it should be prioritized according to the classifier's score. If the action costs money (for example, an operator contacting the customer or a mailing), lift curves can help identify a cutoff point that maximizes returns.

**Note:** The lift curve shows lift on the test set; thus, it represents the expected true lift in actual situations if the underlying distribution of the data does not change significantly. The lift curve in MineSet is computed prior to backfitting and is the same whether or not backfitting is applied.

## Learning Curves in Error Estimation

A learning curve is a graph that shows the error of the classifier generated by an inducer as a function of the number of records used to create the classifier. Typically, the more records used to generate the classifier, the lower its error.

A learning curve is created by generating the specified number of classifiers for each of the points on the curve. Each classifier is generated using a random sample of the records, and its error is estimated using the rest of the records (those not used for training).

Figure 10-14 shows a learning curve for the Decision Tree Inducer on the *churn* dataset. Figure 10-15 shows a learning curve for the Decision Tree Inducer on the *adult* dataset with the label set to gross income binned at $50,000 (so one class is gross income less than or equal to $50,000 and the other class is gross income >$50,000). The X axis shows the number of records used for training the inducer; the Y axis shows the error. The graph consists of four type of points:

- The yellow points are the actual error estimates taken from the runs.
- The white points are averages.
- The blue points interpolate between the white points.
- The red points show a 95% confidence interval about the average based on actual error estimates for each run.

The more runs that are requested, and the bigger the test set (portion used to test), the smaller the confidence interval. The error is generally reduced as more records are used for training.

We can see that for the churn dataset, the error continues to decrease as the training set size grows, while for the adult dataset, there is little advantage to training on the whole dataset. The third point represents about 13,000 records and has an estimated error of 16.96%, while the last point represents about 44,000 records and has an estimated error of 16.85%.

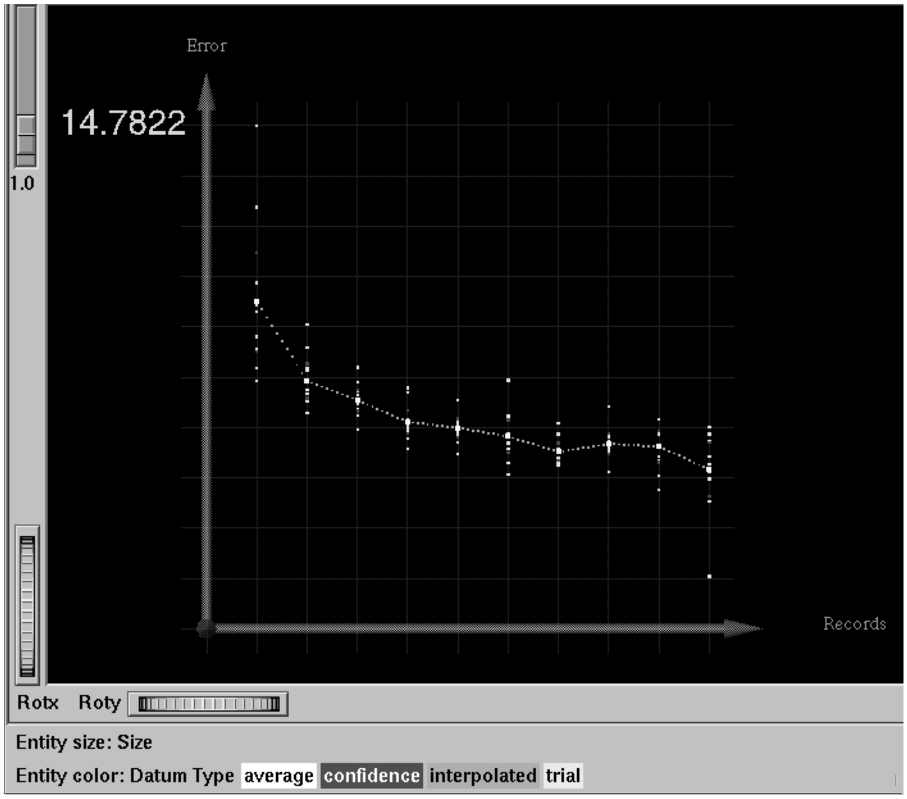
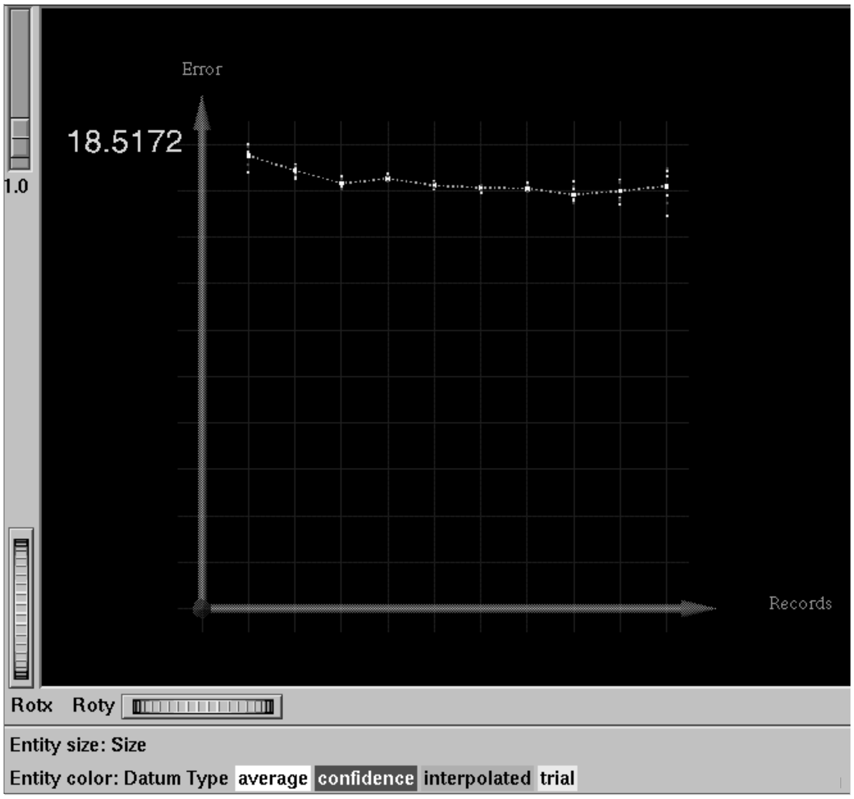


**Figure 10-14** Learning Curve for the Churn Dataset



Entity size: Size

Entity color: Datum Type average confidence interpolated trial

**Figure 10-15** Learning Curve for the Adult Dataset With Label Set to Gross Income Binned at $50,000

A small sample might suffice for most of the study, with the full data used only for the final runs. In many cases, a small sample can result in a sufficiently accurate classifier, with the error reducing only slightly if the number of records is increased (diminishing returns). Once a learning curve is seen, the desired sampling point can be determined, and the “sample” transformation in Tool Manager can be used to generate a sample of this size (see “The Sample Button” in Chapter 3). Small samples reduce the time needed to build a classifier and make the knowledge discovery process more interactive.

## Advanced Options

MineSet supports several advanced options for all inducers. These let you take into account different costs for making mistakes and to take into account an experimental design that has a non-uniform sampling process (that is, some parts of the true population are sampled more heavily than others). Another option lets you create more complicated classifiers which may have better accuracy, at the expense of added compute time.

### Loss Matrices: Not All Mistakes Were Created Equally

Suppose you are trying to classify mushrooms as poisonous or edible. Classifying a mushroom that is actually edible as poisonous might cost you $2, since you are not eating it; however, classifying a poisonous mushroom as edible (that is, eating it) might incur a $10,000 operation.

Figure 10-16 shows a confusion matrix for the *mushroom* dataset with the Decision Tree Inducer when only a ratio of 0.1 (10%) was used for a training set.

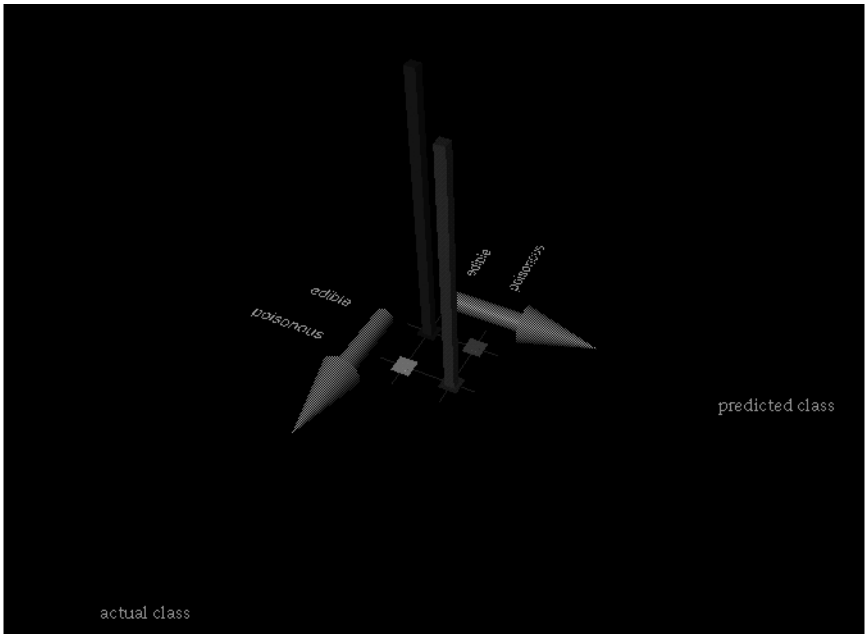


**Figure 10-16** Confusion Matrix for the Mushroom Dataset Using Defaults Settings

Eight records, representing poisonous mushrooms, were classified as edible (0.1%); 15 records, representing edible mushrooms, were classified as poisonous (0.2%). 3793 edible mushrooms and 3496 poisonous mushrooms were correctly classified. While the error-rate for the classifier is only 0.31% (less than one percent), our estimated loss would be $10000*8 + $2*15 = $80,030.

Figure 10-17 shows a confusion matrix for the same dataset, but with the Decision Tree Inducer run using a loss matrix representing the above costs. The new classifier is very conservative and makes no mistakes in classifying a poisonous mushroom as edible; but it makes 1558 mistakes (1543+8) in classifying edible mushrooms as poisonous. The total estimated loss we would incur is thus $10000*0 + $2*1558 = $3116, only 3% of the cost of the classifier that did not take losses into account.

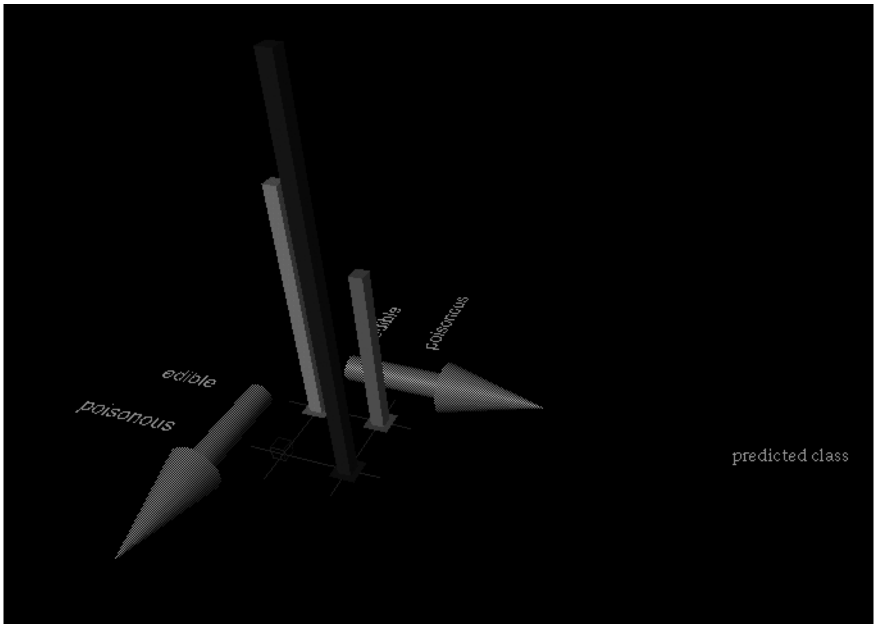


**Figure 10-17** Confusion Matrix for the Mushroom Dataset With Loss Matrix

Loss matrices also allow predicting unknown (null values), which are shown as question marks (?). For example, suppose it costs us $1 to ask an outside expert whether a mushroom is poisonous or edible. In that case, some classifications result in an unknown prediction. Running the Decision Tree Inducer yields the confusion matrix shown in Figure 10-18, where there are 1551 unknowns, and only 15 edible mushrooms are classified as poisonous. The overall cost is thus $10000*0 + $1*1551 + $15*2 = $1581

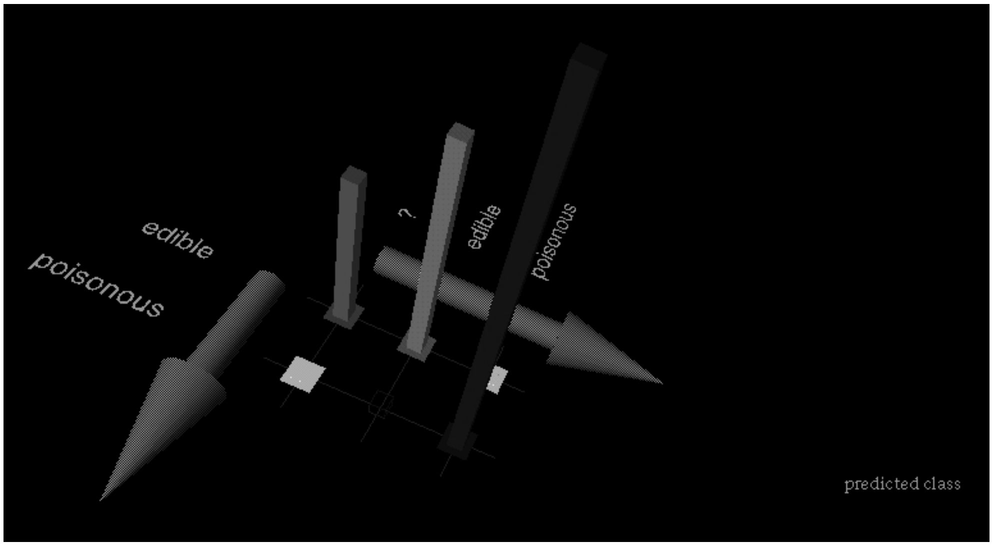


**Figure 10-18** Confusion Matrix for the Mushroom Dataset With Loss Matrix Allowing Unknown Predictions

Note that loss matrices are based on probability estimates made at the leaves of the tree. For reliable estimates:

1. Raise the "split lower bound" in Further Options of Decision Trees and Option Trees from the default value to a higher value (for example: 5). In general, the larger and noisier the training set size, the higher this value should be.
2. Use large training sets. You might need large training sets to get reliable estimates when the costs are not as extreme as in this example.
3. Use Option Trees. While they do not always help, they usually provide better probability estimates that tend to reduce the loss. For example, running the above example with $10000 changed to $100 with unknowns not allowed, yields an estimated loss of $1464 for Decision Trees and an estimated loss of $662 for Option Trees.

## Return-on-Investment Curves

A Return-on-Investment (ROI) curve is similar to a Lift Curve, but displays accuracy in terms of loss rather than in terms of error; taking into account the Loss Matrix used. The points in an ROI curve are ordered by the expected loss for each record, were they to be labeled by the chosen label value. Similarly, the height of each point in the curve indicates the cumulative profit (inverse loss), rather than the cumulative accuracy (inverse error) of all records up to this point. The expected loss is computed by multiplying entries in the Loss Matrix, under the chosen labels column (see "Loss Matrices," under "Advanced Options," below) by the probabilities assigned to the corresponding classes, for the classes by the classifier. Hence, if the classifier is very sure about its prediction, the expected loss will be low, and the record will appear near the left side of the ROI curve.

The idea behind the ROI curve is that the user will take an action for each individual record in the dataset. That action will be the one associated with the chosen label value. For example, in the churn dataset, the action associated with the label Yes, might be to send that person some marketing material. This might stop the person from churning; but the action is costly if done indiscriminately. The peak of the ROI curve shows approximately how much money would have been saved on the test set, if the classifier was used to predict whether or not to send the mailing to a particular person.

Special care needs to be taken when filling out a Loss Matrix for use with a Loss Curve. The column under a certain predicted label determines the resulting ROI curve for that label value. The entries in this column need to represent the expected gain or loss for taking the action associated with that label value, on all of the possible classes. For example, the entry under the column "prediction yes" in churn, under the row "actual value no", may contain the value 2 to indicate that the cost of mailing a brochure (the action associated with "yes") to someone who was not going to churn, is 2 dollars. On the other hand, the entry under the column yes, row yes, may have a value of -10 to indicate that a customer was prevented from churning, saving the company ten dollars over the cost of the mailing.

### Record Weighting: Not All Records Were Sampled Equally

In certain experimental designs, portions of the true population are sampled more frequently than others. For example, while you might want a 1% sample of some population, a small minority that is already 0.1% of the population results in a 0.001% sample, which might be too small (for instance, you might get two people). Record weighting lets you give each record a weight; thus, a subpopulation that was sampled twice as frequently might get a weight of 0.5, while the rest of the population is given a weight of 1.

As another example, a phone company stores all fraudulent phone calls in the dataset, while storing only a small fraction of non-fraudulent calls. By using record weighting, it is possible give each record its true portion of the population.

Finally, some datasets are already aggregated, and the records have a natural “count” associated with them (for example, statistics about cities in the U.S. usually have an associated count of the population). This count attribute can be mapped to weight, which is equivalent to replicating each record by the number of counts.

The semantics of record weighting is that a record weight of 2 is equivalent to two records with a record weight of 1. Floating point weights are allowed.

### Boosting: Accuracy is Sometimes Crucial

In some cases, the most important issue in creating a classifier is its error rate. For example, suppose you have analyzed a dataset for churn prediction to a point that you are satisfied with, and are ready to create a classifier that will predict which of your customers are the most likely to churn. At this point, you are no longer interested in visualizing your classifier, since you have a reasonably good understanding of the factors that are involved. You also want to achieve the best classification accuracy possible. In this case, you might want to enable Boosting, which is an algorithm that creates several different classifiers and combines their predictions using a weighted voting scheme. Boosted classifiers often improve classifier accuracy, by focusing the induction process on examples in the data which are harder to model than others.

Boosting will not always increase accuracy, but it often does. Boosted classifiers cannot be visualized, though you can still see confusion matrices, lift curves, learning curves and ROI curves for boosted classifiers. Boosting is a computationally intensive process, often taking 25 times longer to run than the corresponding inducer without Boosting. Backfitting does not work with Boosted classifiers, because of the special way Boosting weights multiple classifiers and the records used to train them.

The theory behind boosting has not been generalized past two-class problems. MineSet 2.5 and later versions, however, allow you to use boosting with labels that have any number of values. Boosting will not always improve the error rate of induced classifiers; this is especially stressed for problems that have more than two label values.

Boosting works by repeatedly assigning new weight distributions to the training set and inducing classifiers on the reweighted sets. The number of times this occurs is limited by the BOOST_NUM_TRIALS option, which can be set using the *.mineset-classopt* files on the client (see Appendix I, "Command-Line Interface to MIndUtil: Analytical Data Mining Algorithms,"for more information about the *.mineset-classopt* file). The number of classifiers generated may be lower than this parameter if the training set error rate drops to zero before this many classifiers are generated.

The following section describes the options provided for the classifiers by the Tool Manager.

## Inducer Modes in Tool Manager

There are four modes for running an inducer (shown in Figure 10-19).

- Classifier and Error
- Classifier Only
- Estimate Error
- Learning Curve

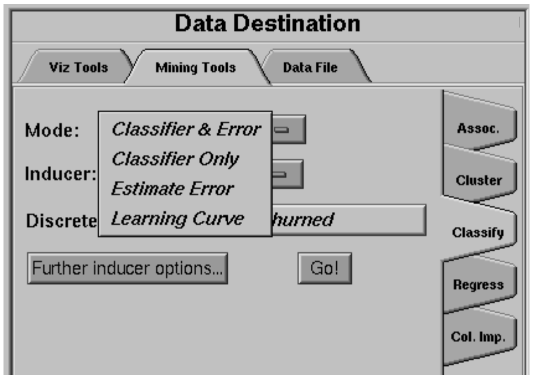


**Figure 10-19** Options for Running the Inducer

The Classifier and Error mode uses a holdout method to build a classifier: a random portion of the data is used for training (commonly two-thirds) and the rest for testing. This holdout proportion can be set in *Further Inducer Options* (see "Error Estimation" on page 324). This method is the default mode and is recommended for initial explorations. It is fast and provides an error estimate.

The Classifier Only mode uses all the data to build the classifier. There is no error estimation. Use this mode when there is little data or when you build the final classifier.

The Estimate Error mode assesses the error of a classifier that would be built if all the data were used (as with Classifier Only mode). Estimate Error uses cross-validation, resulting in long running times. Cross-validation splits the data into *k* folds (commonly 10) and builds *k* classifiers. The process can be repeated multiple times to increase the reliability of the estimate. You can set the number *k* and the number of times in Further Inducer Options, as explained in “Error Options for Inducers,” below. Use this method when there is little data. The induced classifier is exactly the same as the one induced by the *Classifier Only* mode.

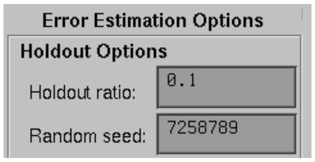
The Learning Curve mode assesses the effect of training set size on the error of a classifier.

## Error Options for Inducers

The following options are available to fine tune the error estimation for the inducers. The Error Options available to you depend on the mode you have chosen.

In both Classifier & Error and Estimate Error, you can set a random seed that determines how the data is split into training and testing sets. Changing the random seed causes a different split of the data into training and test sets. If the error estimate varies appreciably, the induction process is not stable.

In Classifier & Error (see Figure 10-20), you can set the Holdout Ratio of records to keep as the training set. This defaults to 0.666667 (two-thirds). The rest of the records are used for assessing the error.



Error Estimation Options

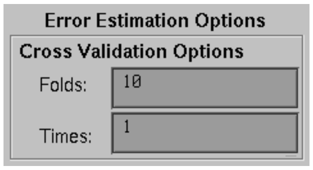
Holdout Options

Holdout ratio: 0.1

Random seed: 7258789

**Figure 10-20** Error Estimation Options With Holdout

In Estimate Error (see Figure 10-21), you can set the number of folds in cross validation and the number of times to repeat the process.



Error Estimation Options

Cross Validation Options

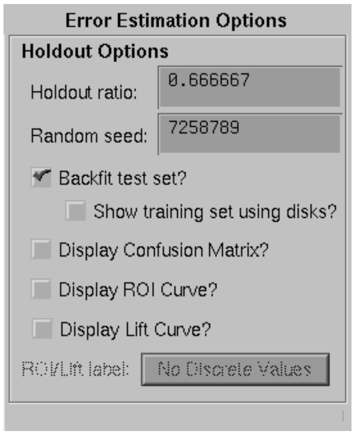
Folds: 10

Times: 1

**Figure 10-21** Error Estimation Options With Cross Validation

## Backfitting

The *Backfit test set* option is a checkmark that can be found under *Further Options* for all inducers when using Classifier & Error mode, and is shown in Figure 10-22. The backfit checkmark is disabled when Boosting is enabled.



Error Estimation Options

Holdout Options

Holdout ratio: 0.666667

Random seed: 7258789

☑ Backfit test set?

□ Show training set using disks?

□ Display Confusion Matrix?

□ Display ROI Curve?

□ Display Lift Curve?

ROI/Lift label: No Discrete Values

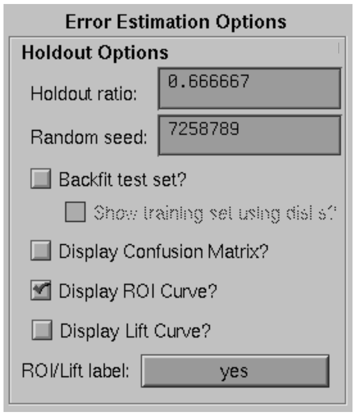
**Figure 10-22** Backfitting, Confusion Matrices, Lift Curve, and ROI Curve Options

## Confusion Matrices

The *Display Confusion Matrix* option is checkmark under *Further Options* for all inducers when using Classifier & Error mode is shown in Figure 10-22.

## ROI Option

The *Display ROI Curve* option is a checkmark under *Further Options* for all inducers when the classifier and Error mode is shown in Figure 10-23. An ROI curve requires a label value to be chosen. An ROI curve is then generated and displayed for that label value.



Error Estimation Options

Holdout Options

Holdout ratio: 0.666667

Random seed: 7258789

□ Backfit test set?

□ Show training set using disl s?

□ Display Confusion Matrix?

☑ Display ROI Curve?

□ Display Lift Curve?

ROI/Lift label: yes

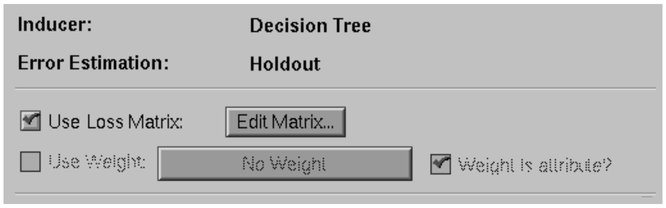
**Figure 10-23** ROI Option for Generating a Return on Investment Curve

## Lift Curves

The *Display Lift Curve* option is a checkmark under *Further Options* for all inducers when using Classifier & Error mode is shown in Figure 10-22. A Lift Curve requires a label value to be chosen. A lift curve is generated and displayed for that label value.

## Loss Matrices

The *Use Loss Matrix* option is a checkmark under *Further Options* for all inducers (See Figure 10-24). The *Edit matrix* button can then be used to define the loss matrix. To avoid unknowns from being predicted, fill the unknown prediction column with the highest value in the matrix.



Inducer: Decision Tree

Error Estimation: Holdout

☑ Use Loss Matrix:

□ Use Weight: No Weight

☑ Weight is attribute?

**Figure 10-24** Enabling Loss Matrices and Setting the Weight Attribute

## Weight Setting

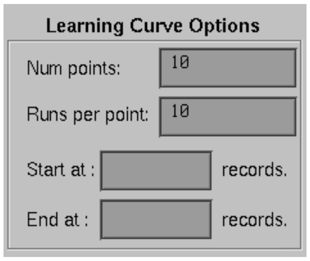
The *Use Weight* option is a checkmark under *Further Options* for all inducers (See Figure 10-24). Choose the column for the weight. The *Weight is Attribute* option determines whether the inducer can use this attribute for classification purposes or not. In certain cases where the weight is a result of a stratified sample that is part of the experimental design, the classifier should not be given access to the weight column as it is not a property of the real-word entity.

## Learning Curves

Learning Curve is a mode in the Classify menu of the Mining Tools tab. It can be used with any of the inducers. When the Learning Curve mode is selected, the *Further Options* dialog box lets you specify *Learning Curve Options* (shown in Figure 10-25), including:

- the number of points in the learning curve,
- the number of runs per point, and
- the number of records to use at the start and end points.

The number of records to use at each intermediate point is calculated automatically.



Learning Curve Options

Num points: 10

Runs per point: 10

Start at : records.

End at : records.

**Figure 10-25** Learning Curve Options

The number of points in the learning curve must be specified; also, it must be greater than or equal to 1. The number of records for the starting and ending points can be specified to allow generating a learning curve for a specific range of the training set. If either of these options are left blank, they are calculated automatically based on the number of points in the learning curve and the total number of records in the training set. This default covers the entire range of the training set. For instance, assume a file containing 80,000 records. If you specified 3 points in the learning curve, the algorithm generates points at 20,000, 40,000 and 60,000 records. Often it is useful to “zoom in” on a smaller range. For example, a learning curve might be generated only for a range of 1000 to 10,000 records.

Generating a learning curve takes a significant amount of CPU time. If $t_i$ is the time to train an inducer on training set *i* (where *i* ranges from 1 to the number of points), and there are *k* runs per point, the total time is $k*\sum_i t_i$ . Increasing the number of runs per point increases the running time proportionally, but improves the estimate of the average. The default value of the number of runs is 3.

The Scatter Visualizer’s filter panel can be used to filter some of the data types shown (average points, confidence intervals, interpolated points, or actual trials). For example, you might want to remove the data points for the trials and confidence intervals and show only the averages and interpolated points.

## OK and Cancel Buttons

Once you have specified the Classification Options, click *OK* to have these options take effect and to return to the Data Destination panel. To return to the Data Destination panel without having changes to the options take effect, click *Cancel*.

### Go! Button

After you have set the options, click the *Go!* button in the Data Destination panel to run the inducer. The appropriate visualizer will automatically be launched.

## The Status Window

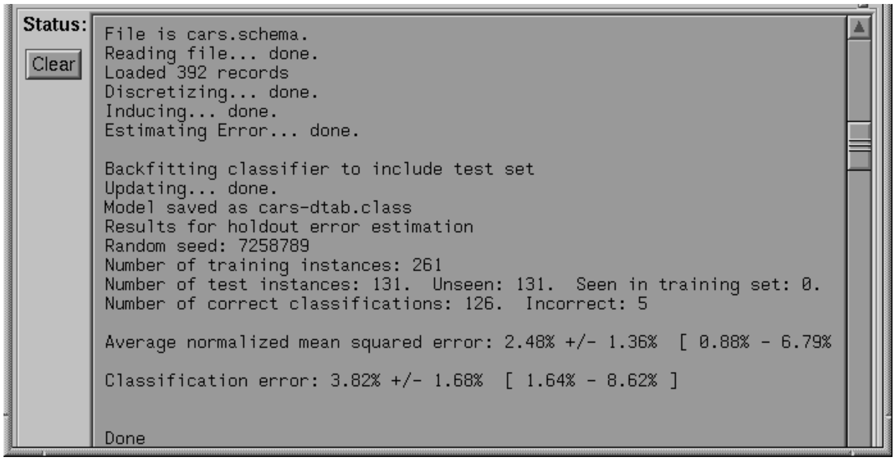
After you press *Go!* in the Data Destination panel, the Status Window at the bottom of the Tool Manager's main window shows the inducer's progress and the output classifier's statistics. It displays specific information for the induced classifier. For example, for Decision Trees it shows the number of nodes, the number of leaves, and the depth of the Decision Tree (Figure 10-26). This information is saved automatically on your workstation under the session file name with a *-dt.out*, *-odt.out*, or *-eviviz.out* extension, depending on whether a Decision Tree, Option Tree, or Evidence Inducer was executed.

For Classifier & Error, the first series of dots represent reading the file, then information about the classifier build progress is shown, then the test set classification progress is shown.

For Classifier Only mode, there is no test set classification phase.

For Estimate Error, the times and folds are shown.

For Learning curves, each average point on the x-axis will be described on a line and each run for that average point will be represented by a dot.



```
File is cars.schema.
Reading file... done.
Loaded 392 records
Discretizing... done.
Inducing... done.
Estimating Error... done.

Backfitting classifier to include test set
Updating... done.
Model saved as cars-dtab.class
Results for holdout error estimation
Random seed: 7258789
Number of training instances: 261
Number of test instances: 131.  Unseen: 131.  Seen in training set: 0.
Number of correct classifications: 126.  Incorrect: 5

Average normalized mean squared error: 2.48% +/- 1.36%  [ 0.88% - 6.79%

Classification error: 3.82% +/- 1.68%  [ 1.64% - 8.62% ]


Done
```

**Figure 10-26** The Status Window

When you have selected the Classifier & Error mode, the Status window contains the following information:

- The random seed used to split the data into training and test sets.
- The number of records used for training the inducer.
- The number of records used for evaluating the resulting classifier; of the test records, how many were seen during training, excluding the label attribute. It is possible to have duplicate records (“seen”) in a dataset; some records can be in both the training and test set. A large value of seen records indicates that there are many duplicate records. If their labels are contradictory, it might be impossible to achieve high accuracy without adding more attributes to the dataset.
- The number of correct and incorrect predictions made.
- The average normalized mean squared error represents the accuracy of the probability estimates. For each test record, the mean squared error is the square of one minus the probability estimate for the correct label value, plus the sum of the squares of the probability estimates for the other (incorrect) label values. The normalized mean squared error is half the mean squared error, which is a value between zero and one. The average normalized mean squared error is the normalized mean squared error averaged over all the records in the test set by their appropriate weights (weighted average).
- The classification error, which is the percent of incorrect predictions.
- Both the average mean squared error and the classification error show the standard deviation of the mean and the confidence interval for the mean. This is the range you can expect from the classifier if the data comes from the same distribution. For error estimates (not losses), a more accurate formula than the usual two-standard deviation rule is used.

When you have selected the Estimate Error mode, the Status window contains the following information:

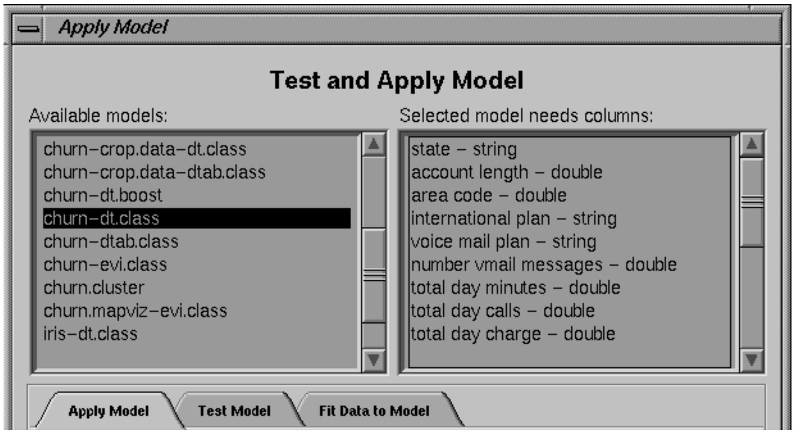
- The number of cross-validation folds and times.
- The random seed.
- The estimated accuracy with standard deviation.
- The 95% confidence interval for the estimated accuracy.

## Applying Models, Testing Models, and Fitting New Data

The *Apply Model* button in the Data Transformations panel lets you:

- take a previously created classifier and apply it to new data.
- test a previously created classifier's performance on the current table.
- fit the current table into a previously created classifier's structure.

On the top left of this dialog box (Figure 10-27) is a list of all classifiers currently available on the server. If you select a classifier, the right-hand side lists the column names and types required by that classifier. If these requirements match the current table, a message at the bottom states this, and the buttons on the bottom (*OK*, *Run Test*, or *Fit Data*) is activated. If the current table does not have all the columns required for the selected classifier, the message at the bottom states this, the columns that are missing are selected in the list on the right, and the button on the bottom is deactivated.



Apply Model

Test and Apply Model

Available models:

churn–crop.data–dt.class
churn–crop.data–dtab.class
churn–dt.boost
churn–dt.class
churn–dtab.class
churn–evi.class
churn.cluster
churn.mapviz–evi.class
iris–dt.class

Selected model needs columns:

state – string
account length – double
area code – double
international plan – string
voice mail plan – string
number vmail messages – double
total day minutes – double
total day calls – double
total day charge – double

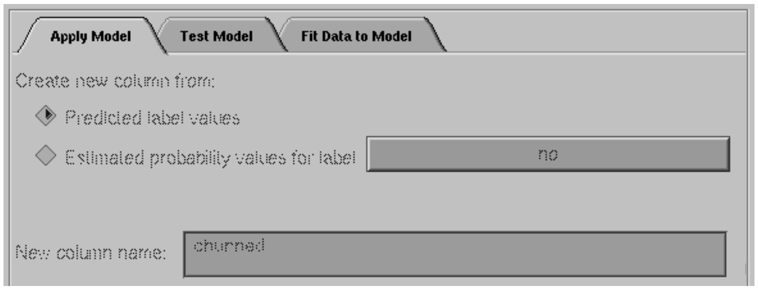
**Figure 10-27** The Test and Apply Model Dialog Box: Selecting a Classifier

## Apply Model

The Apply Model panel is used to apply a previously created classifier to the current table, as shown in Figure 10-28. There are two modes of application for the classifier:

- To *Predict discrete label values* for the records in the current table. For example, if you created a classifier to determine churn, you can use this option to add a column that labels each customer as either likely to churn or not likely to churn.
- To generate *Estimated probability values* for a specified label value. Instead of using the classifier to predict the label value of each record, it is used to estimate the probability that each record has a specified label value (for example, churn = yes). Given the classifier created to determine churn, you can use this option to add a column that indicates the probability that each customer is likely to churn.

The *New column name* text field lets you specify the name of the new column.



Create new column from:

● Predicted label values

○ Estimated probability values for label: no

New column name: churned

**Figure 10-28** The Apply Model Panel

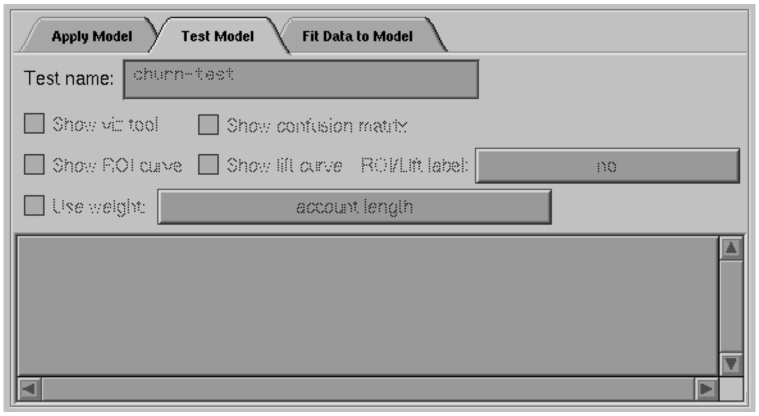
## Test Model

The Test Model panel is used to test a previously created classifier on the current table, as shown in Figure 10-29. The table must contain columns with the names and types required by the selected classifier. Unlike Apply Model, Test Model also requires the table to contain a label column with the same name and type as the label column used when building the classifier.

The Test Model panel has options that lets you

- show the confusion matrix of the classifier on the table records
- show the lift curve of the classifier for a specified label value
- show the ROI curve of the classifier for a specified label value
- show a visualization of the classifier with the table used as the test-set (this is only relevant for Decision Tree and Option Tree classifiers)
- select an attribute to use as the record weight

The text field at the bottom of the Test Model panel shows the results.



Test name: churn-test

□ Show viz tool □ Show confusion matrix

□ Show ROI curve □ Show lift curve ROI/Lift label: no

□ Use weight: account length

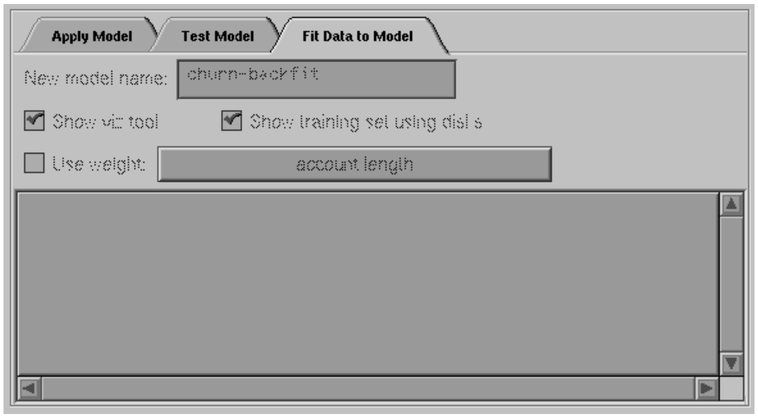
**Figure 10-29** The Test Model Panel

## Fit Data to Model

The Fit Data to Model panel is used to fit the data in the current table to a previously created classifier, as shown in Figure 10-30. This produces a new classifier with the same structure as the original one; however, the new one uses the data from the table to update the probability estimates (see “Backfitting in Error Estimation” on page 328). Because all of the data from the table is being fit into the structure of the classifier, there is no error estimation. Fit Data to Model cannot be used on classifiers that were built using boosting. Use Test Model to evaluate the performance of the new classifier on a separate test set (disjoint from the fit data).

The Fit Data to Model panel has options that lets you

- show a visualization of the new classifier
- specify a name for the new classifier
- select an attribute to use as the record weight



New model name: churn-backfit

☑ Show viz tool ☑ Show training set using dist s

□ Use weight: account length

**Figure 10-30** The Fit Data to Model Panel

## Special Options and Limitations

The following subsections describe how to set special options and the limitations of the inducers.

### Setting Special Options

When the Tool Manager runs an inducer on the server (the MIndUtil program), it passes certain options to the inducers. Not all options are controlled through the Tool Manager GUI. Those options not controlled by Tool Manager take on their default values and can be overridden by setting them in a special file, called *.mineset-classopt*. Tool Manager prepends this file to the options sent. This file is optional. Tool Manager looks for it first in the current directory, then in your home directory. See Appendix I, “Command-Line Interface to MIndUtil: Analytical Data Mining Algorithms” for more details about the options.

The file should contain one line per option, in the following format:

<*OPTION*>=<*value*>

For example, the special option LOGLEVEL increases the amount of information shown during the induction process. The default of zero shows very little information. Level 1 shows other options and slightly more information. Level 2 and higher show large amounts of information about the induction process. These levels are appropriate only if you have a firm understanding of the induction process. (See Appendix K, “Further Reading and Acknowledgments.”)

Note that these options are not part of the saved session. If you send files to other users, you might have to send this file separately to them.

## Default Limits and How to Override Them

Three limits and their respective options are as follows:

- Discrete attributes are ignored if they have more than 100 values. Discrete attributes with many values are usually inappropriate for classification. For example, first names and street addresses are unlikely to form predictive patterns.

  To speed up the induction process, attributes with over 100 values are ignored.

  You can override this value by setting MAX_ATTR_VALS to a higher number. For example, your *.mineset-classopt* file could contain the line

  ```
  MAX_ATTR_VALS=500
  ```
- Discrete labels with over 25 values are not allowed by default. Automatically induced classifiers are rarely appropriate for predicting one of a large number of label values. You should limit the label to a few values (preferably two or three). You can override this default limit by setting the option MAX_LABEL_VALS to a higher value in your *.mineset-classopt* file.
- Boosting works by repeatedly assigning new weight distributions to the training set and inducing classifiers on the reweighted sets. The number of times this occurs is limited by the BOOST_NUM_TRIALS option, which can be set by the *.mineset-classopt* file on the client. The number of classifiers generated may be lower than this parameter if the training set error rate drops to zero before this many classifiers are generated.

## Other Limitations

There are three further limitations:

- Floating point numbers are read into MIndUtil as floats (4 bytes) even if they are represented as doubles (8 bytes) in the database, in the ASCII file, or in the binary file. This limits the precision and magnitude of the representations allowed.
- Attributes of type arrays are always ignored.
- Dates are considered strings. Unless there are few dates, such attributes are usually ignored because of the limit on discrete attributes. You should bin dates before running an inducer.

*Chapter 11*

# Inducing and Visualizing the Decision Tree Classifier

This chapter discusses the features and capabilities of the Decision Tree Inducer. Its associated visualizer, the Tree Visualizer, is described in Chapter 5. This chapter provides an overview of this tool and discusses the ways of using it to generate Decision Tree classifiers. It then explains the Tree Visualizer′s functionality when working with the main window. Finally, it lists and describes the sample files provided for this tool.

**Note:** It is assumed that you have read Chapter 10, “MineSet Inducers and Classifiers,” before proceeding with this chapter.

## Overview

A Decision Tree classifier assigns each record to a class. The underlying structure used for classification is a Decision Tree, such as the one shown in Figure 11-1.

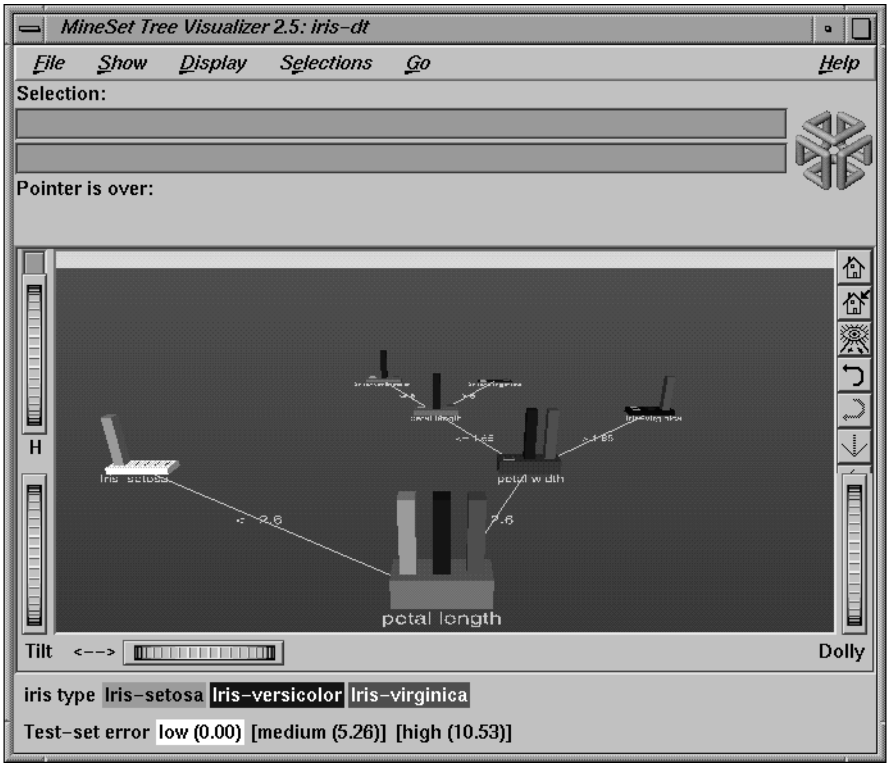


**Figure 11-1** Decision Tree for the Iris Dataset

## Inducing Decision Trees

A Decision Tree classifier is induced (generated) automatically from data. The data, which is made up of records and a label associated with each record, is called the *training set* (see Chapter 10, "MineSet Inducers and Classifiers").

## File Requirements

The Decision Tree Inducer requires a training set, as described in the "Training Set" in Chapter 10. Files are generated by extracting data from a source (such as a MineSet ASCII or binary file, or a table in an Oracle, INFORMIX, or Sybase database). To apply the generated classifier, you should have a dataset of records with the attributes used by the classifier, except that the label need not be present.

## Running the Decision Tree Inducer

There are two ways to run the Decision Tree inducer:

- From the Tool Manager.

  Connect to the server and select a data source (see "Choosing a Data Source" in Chapter 3).

  From the File menu, choose Open New Data File. Log in to a server, and enter the filename. For the example shown here, the filename entered would be `/usr/lib/MineSet/data/iris.schema` as the filename. You'll see four continuous attributes and one discrete attribute in the Data Transformation panel. Since there is only one discrete attribute, the label option automatically shows it. Select the Decision Tree inducer, and ensure you have selected the *Classifier & Error* mode. To run the Inducer, click *Go!*.

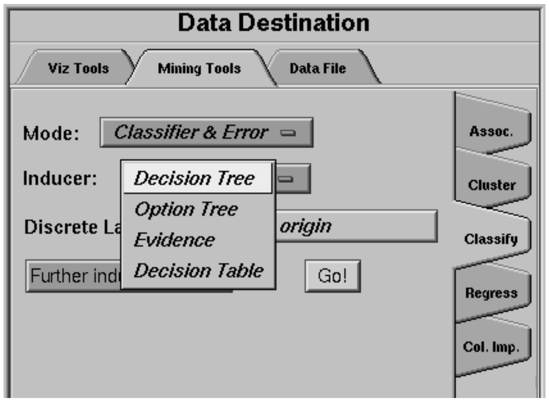
  The status window will show the progress, statistics, and the Tree Visualizer will be launched automatically.

- From the command line.

  To induce a Decision Tree classifier from the command line, refer to Appendix I, "Command-Line Interface to MIndUtil: Analytical Data Mining Algorithms."

## Configuring the Decision Tree Inducer Using the Tool Manager

To access the options for configuring the Decision Tree inducer, select the Mining Tools tab on the Data Destination panel (Figure 11-2). From the tabs at the right, select Classify. Ensure that the inducer you select is Decision Tree (the default). Your selections in the Mode and Inducer menus determine the options available in the Further Inducer Options menu. After you have made your selections in these menus, click *Go!* to run the inducer, which, in turn, creates the classifier.



Data Destination

Mode: Classifier & Error

Inducer: Decision Tree

Discrete La origin

**Figure 11-2** Data Destination Panel in Tool Manager Showing Classifiers

### Discrete Labels

The Discrete Labels menu provides a list of possible discrete labels. Discrete attributes (binned values, character string values, or a few integers) have a limited number of values. You should select a label attribute with few values; for instance, two or three (see "Training Set" in Chapter 10). If there are no discrete attributes, the menu shows *No Discrete Label*, and the *Go!* button is disabled. You then must create a discrete attribute by binning or adding a new column using the Tool Manager's Data Transformations panel.

### Classifier Name

The generated classifier is named with the prefix of the session filename (as determined in Tool Manager) and the suffix *-dt.class*. By default, all classifiers are stored on the server in the *file_cache* directory, which defaults to *mineset_files*. These classifiers can be used for future classification of unlabeled records; that is, they can be used to predict the labels for unlabeled datasets (see “Applying a Model” and “Backfitting in Error Estimation” in Chapter 10).

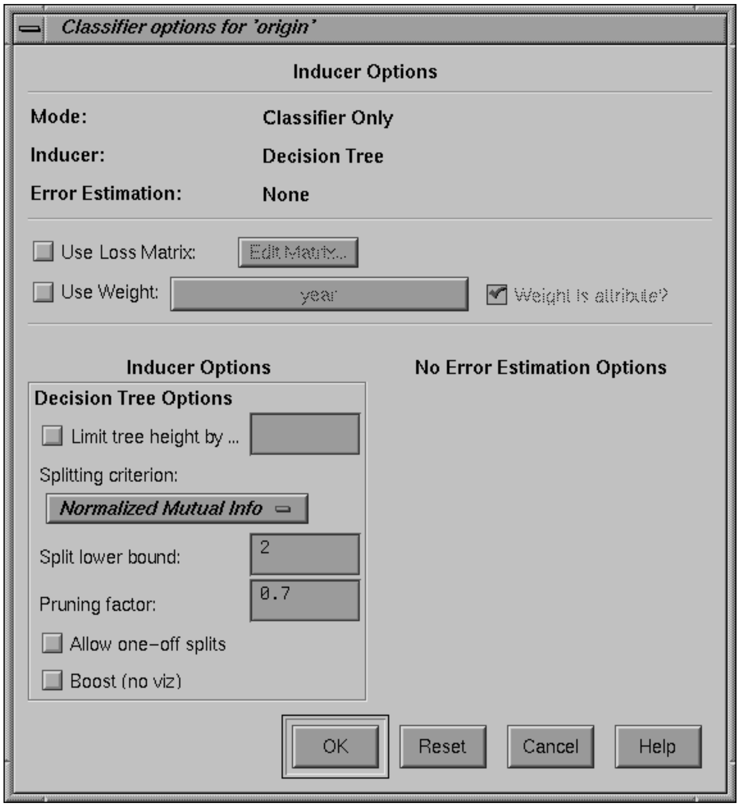
### Parallelization

If you have installed the multiprocessor version of MineSet, it is possible to compute tree-based algorithms in parallel whenever a branch contains over 1000 records. Each node on the tree estimates the best possible split on the corresponding level, and these tasks are performed in parallel. The maximum number of threads a program can spawn is determined automatically by default. You can control the number of threads by changing the parallelization mode in the Preferences panel of Tool Manager (see“The File Menu” in Chapter 3). Parallelization may cause memory fragmentation, causing the largest data sets that can be computed in parallel to be smaller than the largest data sets that can be computed on a uniprocessor.

### Decision Tree Options

Selecting Further Classifier Options causes the Classifier Options dialog box (Figure 11-3) to appear. This dialog box consists of four panels:

- The top panel indicates the choices you made in the Tool Manager’s Data Destination panel.
- The second pane from the top lets you set the loss matrix and the weight attribute. See “Loss Matrices” and “Weight Setting” in Chapter 10.
- The bottom-left panel lets you specify further Inducer Options.
- The bottom-right panel lets you specify the Error Estimation Options (unless the mode you chose in the Data Destination panel was Classifier Only, in which case this area is empty). The options shown in this panel depend on the type of Error Estimation you chose (see “Applying Models, Testing Models, and Fitting New Data” in Chapter 10).



Classifier options for 'origin'

Inducer Options

Mode: Classifier Only

Inducer: Decision Tree

Error Estimation: None

□ Use Loss Matrix: Edit Matrix...

□ Use Weight: year ☑ Weight is attribute?

Inducer Options

No Error Estimation Options

Decision Tree Options

□ Limit tree height by ...

Splitting criterion: Normalized Mutual Info

Split lower bound: 2

Pruning factor: 0.7

□ Allow one–off splits

□ Boost (no viz)

**Figure 11-3** Further Inducer Options

### Decision Tree Inducer Options

To fine-tune the Decision Tree induction algorithm, you can change the following Decision Tree inducer options (see Figure 11-3).

- *Limit tree height by*

  By default, there is no limit to the height (number of levels) in the Decision Tree. Limit the height by clicking the checkbox and typing a number for the limit. Limiting the number of levels speeds up the induction and is useful for studying the Decision Tree without the distraction of too many nodes. Note that restricting the size decreases the run time but might increase the error rate. Setting this option does not affect the attributes chosen at levels before the maximum level.

- *Splitting criterion*

  This option offers three splitting criteria selections. The definitions below are technical. For a given problem, it is difficult to know which criteria will be best. Try them all, and select the one that leads to the lowest error estimate - or to a Decision Tree you find easiest to understand.

  *Mutual Info* is the change in purity (that is, the *entropy*) between the parent node and the weighted average of the purities of the child nodes. The weighted average is based on the number of records at each child node.

  *Normalized Mutual Info* (the default) is the Mutual Info divided by the log (base 2) of the number of child nodes.

  *Gain Ratio* is the Mutual Info divided by the *entropy* of the split while ignoring the label values.

  *Normalized Mutual* Info and *Gain Ratio* give preference to attributes with few values.

- *Split lower bound*

  This is a lower bound on the weight (normally the number of records if weight was not set) that must be present in at least two of the node’s children. The default for this option is 2. For example, if there is a three-way split in the node, at least two out of the three children must have a weight of two or more (two records or more if weight is not set). This provides another method of limiting the size of the Decision Tree.

  Increasing the split lower bound tends to increase the reliability of the probability estimates, because the number of records at each leaf is larger. It also creates smaller trees and decreases the induction time. If you expect the data to contain noise (errors or anomalies), or if you use the tree for estimating probabilities (see “Applying a Model” in Chapter 10), increase the split lower bound to 5 or more. If your dataset is very small (< 100 records), you might want to decrease this number to 1.

- *Pruning factor*

  A Decision Tree is built based on the limits imposed by Limit Tree Height and Split Lower Bound. Statistical tests are then made to determine when some subtrees are not significantly better than a single leaf node in which case those subtrees are pruned.

  The default pruning factor of 0.7 indicates the recommended amount of pruning to be applied to the Decision Tree. Higher numbers indicate more pruning; lower numbers indicate less pruning. If your data might contain noise (errors or anomalies), increase this number to create smaller trees. The lowest possible value is 0 (no pruning); there is no upper limit.

  Pruning is slower than limiting the tree height or increasing the split lower bound because a full tree is built and then pruned. Pruning, however, is done selectively, resulting in a more accurate classifier

- *Boosting*

  Boosting is employed to improve accuracy of classification, although it is a time-intensive process. Visualization is not performed during boosting.

  The estimated error appears in the status window, as the process runs. This estimated error is the result of the algorithm repeatedly assigning new weight distributions to the training set, and inducing a classifier on the reweighted sets. Estimating error in this manner is normally done after you have done a visualization to gain insight into the dataset. See “Boosting: Accuracy is Sometimes Crucial” in Chapter 10 for more information on boosting.

- *Allow one-off splits*

  Clicking this checkbox allows the inducer to make two-way splits on nominal attributes that have more than two values. Normally, splits on nominal attributes have as many lines as they have values (see the section on Decision Nodes, below). For example, a split on the attribute “color” might have lines for red, green, yellow, and blue. If one-off splits are enabled, then the inducer can also make splits with just two lines, for example red, and not red. One-off splits isolate exactly one of the possible values that the column can have. These kinds of splits may be useful when the data contains attributes with many possible values, some of which are exceptionally good at discriminating the label.

# Working in the Tree Visualizer’s Main Window

The Tree Visualizer’s main window shows the Decision Tree. This Decision Tree consists of nodes connected by lines (see Figure 11-1).

## Nodes

There are two types of nodes:

- decision
- leaf

### Decision Nodes

Decision nodes specify the attribute that is tested at the node. Values (or ranges of values) against which the attributes are tested are shown at the lines. Each possible value for the attribute matches exactly one line. For example, the root of the Decision Tree in Figure 11-1 tests the attribute petal_length; the two lines emanating from the node specify the ranges of values for that attribute (< = 2.6 and >2.6,) so that every possible value matches either the right branch or the left branch. If the value is unknown and there is no line labeled with a question mark (?), the majority class of the current node is predicted.

### Leaf Nodes

Leaf nodes in a Decision Tree specify a class. Follow the left branch in Figure 11-1 from the root to a leaf labeled iris-setosa. Note that the Decision Tree classifier classifies all records with petal_length < = 2.6 inches as belonging to the class iris-setosa.

### Node Information

The vertical bars atop each node show the distribution of the classes at the node. The base of each node has a height and a color. The height corresponds to the weight of the training set records that have reached this node (this is the number of records if weight was not set). In general, the higher the weight, the more reliable the class distribution at every node.

The color of the base indicates the error estimate of the subtree: indigo shows high error, grey indicates medium, white indicates low error. The color of the base is black if no test set records reached a node; thus, there is no error estimate.

Pointing to a node causes the following information to be displayed:

- *Subtree weight* — The weight of the training set records in the subtree below the node pointed to. This value is mapped to the height of the base.
- *Test set error/loss* — An estimate of the subtree error (or loss if a loss matrix was given). The number after the +/- is the standard deviation of the estimate. The higher the standard deviation, the less accurate the error estimate. The error/loss estimate and the standard deviation are less reliable for leaves with few records or when the test set error is close to 0% or 100%.
- *Test set weight* — The weight of records from the test set that reached the node (number of records if weight was not set).
- *Purity* — A number from 0 to 100 indicating the skewness of the label value distribution at the node. If a node has records from a single class, the purity is 100. If the label values have the same weight, the purity is 0. The purity is computed after backfitting.

When backfitting is enabled and *Display training set as disks* checked on, the vertical bars show the distribution of the training set as disks. The heights of the disks are on the same scale as the heights of the bars. You should expect the disks to appear about as high on the bars as the value used for the *Holdout ratio* in Further inducer options.

Note that only Classify & Error yields the test set error/loss and weight. You can use the Test Classifier option (see "Applying Models, Testing Models, and Fitting New Data" in Chapter 10) to generate a visualization based on an existing classifier and a test set.

## Lines

All possible outcomes are marked on the horizontal lines emanating from each decision node. Each line indicates the value (or range of values) against which the attribute of that node was tested.

### Using the Main Window to Classify Records

To classify a record, start at the root, and test how to branch at every decision node. By following the appropriate lines based on the record's attribute values, you reach a leaf node. The label, or class, associated with the leaf node is the predicted classification of the record.

Some decisions are quickly made and take a shorter path (for example, petal_length <=2.6 implies iris-setosa). Other decisions can take a longer path (for example, the right branches, petal_length > 2.6 and petal_width > 1.65). In general, every leaf corresponds to a rule that is the conjunction of all tests at the decision nodes and all the values (or ranges of values) on the lines leading to it from the root.

In the root of the tree shown in Figure 11-1, the error rate is 6%, with a standard deviation of 3.39%. The standard deviation is high because the file is small, and the test set only has 50 records. The purity is 0.0, indicating that the distribution is uniform.

The left child of the root has 0 test set error and a purity of 100 because all records with petal_length <=2.6 inches are of the iris-setosa class; thus, the prediction of iris-setosa is likely to be very accurate for all records with petal_length <=2.6 inches. The right child of the root has an estimated error of 8.57%. In this child, which matches records whose petal_length > 2.6 inches, there are no records belonging to the iris-setosa class; thus, the class is more likely to be iris-versicolor or iris-virginica. Because only two possibilities exist at this node, there is a higher purity than at the root (36.91).

The Decision Tree leaves segment the data into clusters sharing the same classification rule (path that leads to each leaf). By looking at the leaves, it is possible to see clusters that share the same set of properties.

## External Controls

The external controls for the visualizer associated with the Decision Tree classifier are the same as those for the Tree Visualizer. For a description of these controls, see "External Controls" in Chapter 5.

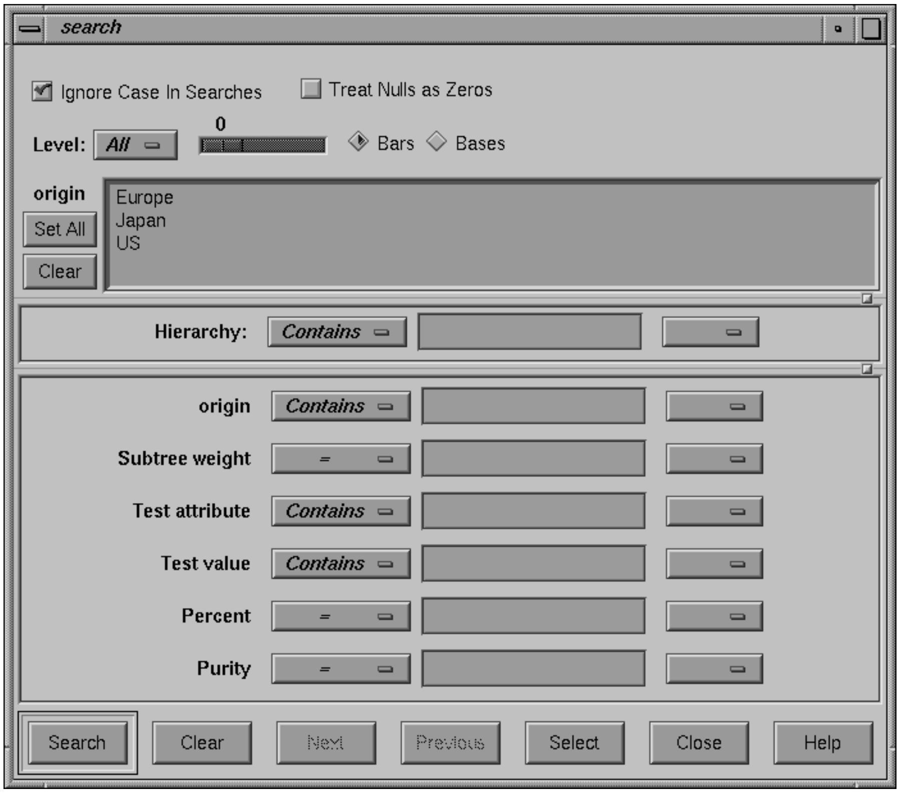
One particularly useful control for decision trees is to click the right mouse button when pointing to a node. This shows the list of children of that node.

## Pulldown Menus

The pulldown menus for the visualizer associated with the Decision Tree classifier are the same as those for the Tree Visualizer. For a description of these menus, see “External Controls” in Chapter 5.

### The Search and Filter Panels

Select Search Panel and Filter Panel in the Show menu to bring up a dialog box that lets you specify criteria to search/filter for objects (Figure 11-4). The panels are the same ones described in “The Search Panel” in Chapter 5; however, the item choices for decision trees are always the same. These are described below.



search

☑ Ignore Case In Searches ☐ Treat Nulls as Zeros

Level: All 0 ◆ Bars ◇ Bases

origin

Europe
Japan
US

Hierarchy: Contains

origin Contains

Subtree weight =

Test attribute Contains

Test value Contains

Percent =

Purity =

**Figure 11-4** Tree Visualizer’s Search Dialog Box

The search/filter can be restricted to specific class labels, either by selecting the values in the class list or by using the class item, which allows more powerful comparison operators (such as Matches). Other items are described below:

- *Subtree weight* lets you restrict the search/filter to bars or bases (depending on the choice of the radio button bars/bases) with a given weight (number of records if weight is not set) for the subtree. For example, you can restrict the search to bars containing a weight of at least 50.
- *Test attribute* lets you restrict the search/filter to nodes labeled by the given value that the node is testing. Note that decision node labels represent the test attribute, while leaf node labels show the predicted label. For example, if you select *Test attribute contains age*, only nodes that test the value of age are considered.
- *Test value* lets you restrict the search/filter to nodes having an incoming line labeled with a value you specify.
- *Percent* lets you restrict the search/filter to bars representing a percentage of the overall weight at a node. For example, you might want to find all nodes such that a given class accounts for more than 80 percent of the weight. To do this, click the class label, and select *Percent > 80*. Setting this item is meaningless if you select bases and not bars (the value for the bases is 0).
- *Purity* lets you restrict the search/filter to nodes with a range of purity levels. For example, if you want to look at pure nodes (with one class predominant), you can select *Purity > 90*.
- *Test-set subtree weight* lets you restrict the search/filter to subtrees with a given test-set weight (number of test-set records if weight is not set).
- *Test set error/loss* lets you restrict the search/filter to nodes with a range of estimated error/loss.
- *Mean error/loss standard deviation* lets you restrict the search/filter to nodes with a range of estimated standard deviation for the test set error/loss.
- *Level* lets you restrict the search/filter to a specific level or range of levels. For example, you can search only the first five levels.

The following items and options are less useful for decision trees.

- *Hierarchy* finds all the nodes and lines that match the given value at the tail of the path from the root. It then marks the children of these nodes.
- *Treat Nulls as Zeros* is not used by the Decision Tree inducer because there are no null items generated for decision trees.

Once the search is complete, yellow spotlights highlight objects matching the search criteria. To display information about an object under a yellow spotlight, move the pointer over that spotlight; the information appears in the upper left corner, under the label "Pointer is over:." To select and zoom to an object under a yellow spotlight, left-click the spotlight; if you press the Shift key while clicking, zooming does not occur.

Once the filtering is complete, the scene shows only nodes matching the filtering criteria.

## Sample Files

The following examples illustrate cases in which the Decision Tree inducer can be useful. Each of these examples is associated with a sample data file provided with MineSet. By running the inducer, you can generate the *-dt.treeviz* files described below.

**Note:** The data files, which have a *.schema* extension, are located in */usr/lib/MineSet/data* on the client workstation. The classifier visualization files, which have a *-dt.treeviz* extension, reside on the client workstation in */usr/lib/MineSet/treeviz/examples*.

### Churn

When customers change their phone carrier from one telecommunications company to another, this is termed "churning." This is a common problem in the telecommunications industry. The file */usr/lib/MineSet/treeviz/examples/churn-dt.treeviz* shows a Decision Tree classifier induced for this problem. The file was generated by running the inducer on */usr/lib/MineSet/data/churn.schema* with the label set to churn (yes, no). The file given is fictitious, but based on patterns found in real data.

Note that in this tree the root split is on the amount of time the customers talk during the day (total day minutes). Customers who talk more than 264 minutes per day churn at a significantly higher rate than those who don't (60% versus 11%). These also are probably the most profitable customers.

The left subtree represents customers who talk less than 264 minutes per day. They have a churn rate of 11%; but if they make more than three customer service calls, the churn rate increases to 49%.

The right subtree represents customers who talk over 264 minutes per day. They have a churn rate of 59%; but if they have a voice-mail plan, the rate decreases to 9.3%. If they do not have a voice-mail plan, the churn rate is almost 75%.

### Origin of Cars

The *cars* dataset contains information about different models of cars from the 1970s and early 1980s. Attributes include weight, acceleration, and miles per gallon (mpg). The file */usr/lib/MineSet/treeviz/examples/cars-dt.treeviz* shows the Decision Tree classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/cars.schema* with the label set to origin (Japan, U.S., Europe). If you have a dataset of car attributes, you might want to know what characterizes cars of different origins.

Note that in the tree the left split is on brand. The root split is not brand because the Decision Tree inducer penalizes multi-way splits; and the split on cubic_inches was deemed a better discriminator. You can use the Tool Manager Remove Column transformation to hide the brand, thus making the problem more interesting.

In the Decision Tree, you can see that cubic inches is an excellent discriminator for U.S.-made cars. Cars with large engines (>169.5 cubic inches) are all made in the U.S., but smaller cars are made everywhere. By choosing Selections > Show Original Data, you can see that the one car with a big engine that was not made in the US is a Mercedes. Note that in this tree, the root node (that is, the entire training dataset) has many more U.S. cars (62.50%), yet after a single split on the cubic inches attribute, it is more difficult to predict the origin of cars with small engines. The purity of the root is 16.2 showing that there is one class (U.S., in this case) that is dominant. The right node (cubic inches > 169.5) has purity 96.81, indicating that we have identified a very pure subpopulation (almost all cars with large engines were made in the U.S.). Indeed, the error rate for the right subtree is estimated at 0% (green base). The left node from the root has purity 0.23 and a much higher error rate of 31.25% (orange base). This subproblem is much harder than the original one: the number of records for each class is approximately the same.

### Gender Attribution

The *adult* dataset contains information about working adults. This dataset was extracted from the U.S. Census Bureau. It contains data about people older than 16, with a gross income of more than $100 per year who work at least one hour a week. You might want to know how to characterize males and females. The file */usr/lib/MineSet/treeviz/examples/adult-sex-dt.treeviz* shows the Decision Tree classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/adult.schema*, with the label set to *sex*. Note that this dataset contains almost 50,000 records; thus, running the Decision Tree Inducer can take several minutes when you run this on your workstation.

The resulting visualization provides the following insights:

- Relationship is a giveaway attributes for some values. Husbands usually are male. (Interestingly, there is one husband that is a female, showing data quality problems at the Census Bureau, which does not recognize same-sex marriages.) Similarly, if the person is a wife, the person is usually a female, except for three records that show otherwise.

To make the problem more interesting, remove the relationship attribute and generate a new Decision Tree. Note that

- The most important attribute is marital status.
- From the height of the bases, most people are either divorced, married to a civilian spouse, or never married. Few are married with spouse absent, separated, married to armed-forces spouse, or widowed.
- The distribution at the root shows more males in this dataset. (This database contains information about working adults and is not representative of the entire population.)
- The left-most node contains divorced working adults. We can see that the distribution is more balanced than at the root (60% female, 40% male). The second node contains married working adults. We can see that 89% are males. The third node contains working adults that have never married. Their numbers are approximately equal to those in the divorced group, with slightly more males. The right-most node contains working widowed adults, of which 81% are females (probably because of their higher life expectancy).

If you want to target working females for a new product, you can use the search panel to identify segments that have a large population of females. You can do this by choosing

- sex matches female (click female on the top portion of the window).
- subtree weight > 1000
- percent > 80

Three yellow spotlights show the matching nodes. Since two are on one path, look at the node closest to the root (on the right). The paths translate into the rules

```
marital status = Widowed implies that 81.23% are female
```

```
marital status = Divorced and occupation =
     administrative clerical implies that 87.67% are female
```

In this training set, 1233 (widowed) and 1045 (divorced and occupation) females satisfy these rules out of 16,192 at the root. This simple segment contains over 14% of working women.

### Salary Factors

If you have a dataset of working adults, you might want to find out what factors affect salary. You might then divide the records into two classes: those adults earning ≤ $50,000 a year, and those earning more. Each record then has an attribute with two values: "–50,000" and "50,000+". You can run a MineSet classifier to help determine what factors influence salary. The file */usr/lib/MineSet/treeviz/examples/adult-salary-dt.treeviz* shows the Decision Tree classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/adult.schema* with *gross_income* binned at the user-specified threshold of 50000 and the label set to *gross_income_bin*.

The resulting visualization provides the following insights:

- The root, which represents the entire training set, shows 76.07% of the working adults earn ≤ $50,000.
- Age is the most important factor. Only 3.07% of the people under 27 years old earn more than $50,000. Note that the base color is green, indicating a very accurate rule (about 3% error rate).
- Education is an important factor for predicting salary for people over 27 years old. The Census Bureau assigns education levels to each person. The Decision Tree classifier splits on 12.5; the level 13 matches a Bachelor's degree. People with a Bachelor's degree or higher, go right to the node where about 55% earn over $50,000.
- Of the segment that is older than 27 years and well educated, relationship is an important predictor of salary. For those persons that are married, chances of earning $50,000 or more increase to 73% for husbands and 75% for wives. (Note, however, that the node containing wives has a small base, indicating that few females match this rule.) If the person in this group is not married, chances of earning $50,000 or more decrease to 27% for males and 25% for females.

### Iris Classification

In this dataset, each record describes four characteristics of iris flowers: petal width, petal length, sepal width, and sepal length. Each iris was further classified into the types iris-setosa, iris-versicolor, or iris-virginica. The goal is to understand what characterizes each iris type.

Before running a classifier, click the Importance tab in the Tool Manager's Classifiers tab; then click *Go!*. You obtain a ranking of the importance of the features: petal_width, petal_length, and sepal_length. You can map these to the axes in the Scatter Visualizer, with the iris_type mapped to the color, and see the clusters.

The file */usr/lib/MineSet/treeviz/examples/iris-dt.treeviz* shows the Decision Tree classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/iris.schema*.

Running the Tree Visualizer, you can see that the root has 6% error rate, even though the purity is very low (0). The purity measures the skewness of the distribution, and, at the root, the distribution is perfectly uniform: 50 records for each label value. The left branch (petal-length <= 2.6 inches) goes to a green node (zero error) containing only iris-setosas. The other branches are also quickly able to separate the classes using another test on the petal_width. The path petal-length > 2.6 and petal-width £ 1.65 and petal-length > 5 ends with an impure leaf containing 4 records. There are three records of type iris-virginica and one of iris-versicolor. The Decision Tree did not split this node because it was deemed insignificant (by default, every split must contain two children with at least a weight of two). The node color is also black, indicating that no test instances reach this node, so we do not have an estimated error rate for it.

To summarize: the flowers with petal length £ 2.6 inches are predicted as iris-setosa, those with petal length > 2.6 inches and <=5 inches and petal width £1.65 inches are predicted as iris-versicolor, and those with a petal length >2.6 inches and a petal width > 1.65 or petal length > 5 inches and petal width <= 1.65 are predicted as iris-virginica.

Note that because the Decision Tree makes binary splits on continuous attributes while Column Importance discretizes the data, the root split of the tree is different from the first attribute in column importance (see Chapter 17 for more details).

### Mushroom Classification

The file */usr/lib/MineSet/treeviz/examples/mushroom-dt.treeviz* shows the Decision Tree classifier induced for the classification of mushrooms. This file was generated by running the inducer on */usr/lib/MineSet/data/mushroom.schema*.

The goal is to understand which mushrooms are edible and which are poisonous, given this dataset. There are over 8000 records in this set; thus, running this inducer might take several minutes.

Each mushroom has many characteristics, including cap color, bruises, and odor. If you build a Decision Tree classifier, you can see that using only the odor attribute lets you determine in 50% of the cases whether the mushroom is poisonous or edible. If the mushroom has no odor, there is a 3.4% chance it is poisonous. The next attribute to look at is the shape of the stalk. If it tapers, the mushroom is edible; but if it enlarges, there is a 11.6% chance the mushroom is poisonous. There are 1032 mushrooms that reach this node. You can follow the tree down further nodes to see what other attributes to consider.

### Party Affiliation

This dataset consists of voting records. The goal is to identify the party a congressperson belongs to given data about key votes. The dataset includes votes for each member of the U.S. House of Representatives on the 16 key votes identified by the *Congressional Quarterly Almanac* (*CQA*). The CQA lists nine types of votes: voted for, paired for, and announced for (these three are simplified to yes); voted against, paired against, and announced against (these three are simplified to no); voted present, voted present to avoid conflict of interest, and did not vote or otherwise make a position known (these three are simplified to an unknown disposition).

Before running a classifier, look at the 16 votes to see if you can perceive which features are important. Then run the Decision Tree classifier.

The file */usr/lib/MineSet/treeviz/examples/vote-dt.treeviz* shows the Decision Tree classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/vote.schema*.

### Breast Cancer Diagnosis

The breast cancer dataset contains information about females undergoing breast cancer diagnosis. Each record is a patient with attributes such as cell size, clump thickness, and marginal adhesion. The final attribute is whether the diagnosis is malignant or benign. The file */usr/lib/MineSet/treeviz/examples/breast-dt.treeviz* shows the Decision Tree classifier induced for this problem. This file was generated by running the inducers on */usr/lib/MineSet/data/breast.schema*.

The Decision Tree shows that uniformity_of_cell_size is a very strong discriminatory attribute. While the root distribution is about 65% versus 35% (purity is 7.07), the two children of the root are much more skewed, with the left node having an error rate of only 1.29%. The root alone is an excellent discriminator: if you limit the tree height to a single level (see “Decision Tree Inducer Options”), the error rate is 7.3%.

### Hypothyroid Diagnosis

The hypothyroid diseases dataset is similar to the one for breast cancer. The file */usr/lib/MineSet/treeviz/examples/hypothyroid-dt.treeviz* shows the Decision Tree classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/hypothyroid.schema*.

There are 3163 records in this dataset and most of them do not have hypothyroid (95.23%). While this means that one can predict "negative" and be correct with high probability, it's those people that have hypothyroid that we are most worried about: the false negatives are very important. By selecting a confusion matrix from Further Inducer Options, you'll see that there are five patients with Hypothyroid who were misclassified.

Looking at the Decision Tree, you can see that the root node is "green" (highly accurate). The single attribute on "fti" at the root shows that it is relatively easy to identify many of the negative diagnosis. People with high fti are 99.7% negative, and all those where the value is unknown are also negative (perhaps the doctor decided not to measure this attribute because something else was obvious), but the rest (218 people) are hard cases (node base is colored orange). We started with 3163 records, but only 218 are really "interesting" to mine because it was very easy to determine the classification of most cases. In this example most of the data is uninteresting and you want to concentrate on a small part quickly. Of the 218 people, you can see that about 66% are positive and 34% negative.

As you move down the tree, increase the height scale (slider on the top left of the visualizer) to see the different heights. The node that catches most of the people with hypothyroid has the conditions "fti <= 64.5 and tsh > 5.95." It contains 140 of the 151 records that have hypothyroid.

### Pima Diabetes Diagnosis

This dataset is a diagnosis problem for diabetes using statistics gathered from a Native American tribe in Phoenix, Arizona. The task is to determine whether a patient has diabetes, given some medical attributes, such as blood pressure, body mass, glucose level, and age.

The file */usr/lib/MineSet/treeviz/examples/pima-dt.treeviz* shows the Decision Tree classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/pima.schema*.

### DNA Boundaries

There are 3,186 records in this DNA dataset. The domain is drawn from the field of molecular biology. Splice junctions are points on a DNA sequence at which “superfluous” DNA is removed during protein creation. The task is to recognize exon/intron boundaries, referred to as EI sites; intron/exon boundaries, referred to as IE sites; or neither. The IE borders are referred to as “acceptors” and the EI borders are “donors.” The records were originally taken from GenBank 64.1 (*genbank.bio.net*). The attributes provide a window of 60 nucleotides. The classification is the middle point of the window, thus providing 30 nucleotides at each side of the junction.

In this example, the root of the Decision Tree shows the distribution of the three classes. By pointing to the bars, you can see that the composition is about 24% exon/intron, 24% intron/exon, and 52% none. The “left_01” in front of the root node indicates that this is an important attribute to look at first. The “left_01” notation refers to the first nucleotide found to the left of the splice junction in question. The choices of attribute values for this first nucleotide (and all nucleotides in general) are the “A”, “G”, “T”, and “C” nucleotides. If the “left_01” nucleotide is a “G”, then the “G” branch is taken and followed to the next node, where the distribution now shows that such a nucleotide is more likely to be an “exon/intron” or an “intron/exon” than at the root: the distribution is 34% for “exon/intron,” 42% for “intron/exon”, and 24% for “none.” If the “left_01” nucleotide is an “A”, “T”, or “C”, then the corresponding “A”, “T”, or “C” branch is taken instead and in all three cases, the probability of “none” increases dramatically (87%, 87%, and 95% respectively). This testing and branching process is repeated until the final node with the predicted class (“exon/intron”, “intron/exon”, or “none”) is reached.

For this dataset, the Evidence Classifier (Chapter 13) is more appropriate than a Decision Tree due to the probabilistic nature of this domain. This can be verified by comparing the estimated error rates.

*Chapter 12*

# Inducing and Visualizing the Option Tree Classifier

This chapter discusses the features and capabilities of the Option Tree inducer. This chapter provides an overview of this tool and discusses methods for using it to generate Option Tree classifiers. The Option Tree Visualizer's functionality is the same as for Decision Trees and was described in Chapter 11. Finally, it lists and describes the sample files provided for this tool.

**Note:** It is assumed that you have read Chapter 10, "MineSet Inducers and Classifiers," and Chapter 11, "Inducing and Visualizing the Decision Tree Classifier" before proceeding with this chapter.

## Overview

An Option Tree classifier assigns each record to a class. The underlying structure used for classification is a Decision Tree, as described in Chapter 11. Figure 12-1 shows an Option Tree where the goal is to predict for the *cars* dataset the origin of a car built in the 1970's or early 1980's (the origin points being the U.S., Japan, or Europe). Option Trees extend a regular Decision Tree classifier by allowing *Option Nodes*. An Option Node shows several options that can be chosen at a decision node in the tree. For example, in Figure 12-1, the root is an option node with five options:

1. cubicinches
2. cylinders
3. weightlbs
4. mpg
5. brand

Option nodes serve two purposes:

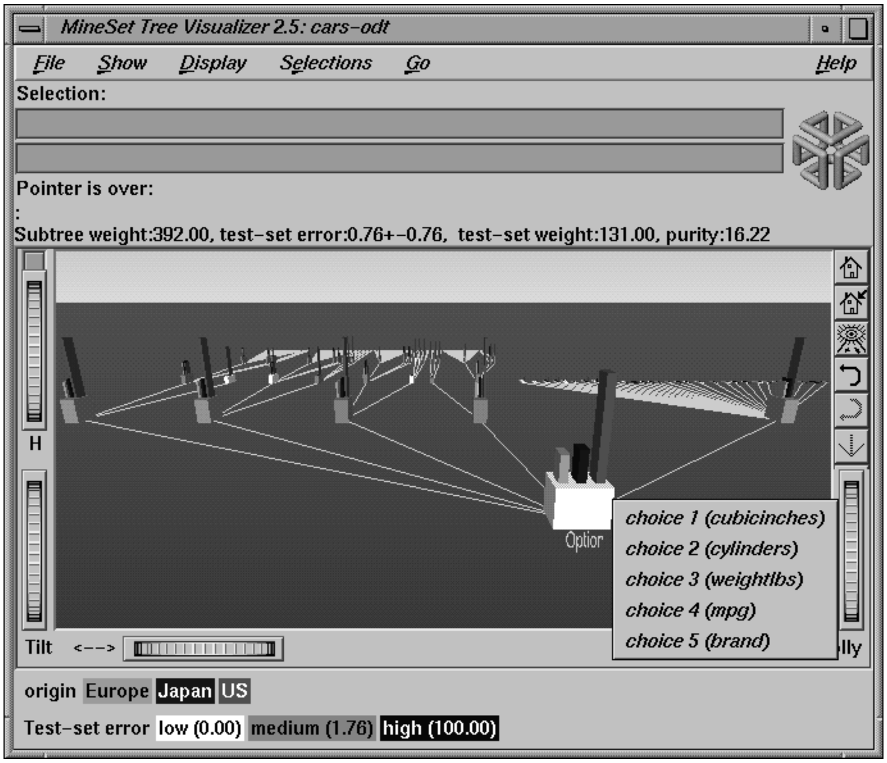
1. They enhance comprehensibility of the factors affecting the determination of class label by showing several choices that can be made. Instead of using a single attribute at a node, an option node provides you with several options. When flying over the tree, you can choose to follow an option that

   - you believe is easier to understand, or
   - you believe is better for predictions based upon your previous experience, or
   - you select based on the error estimate

   In the *cars* dataset shown in Figure 12-1, you can fly down the *cylinders* subtree because it has few values, or you can fly down to the *weightlbs* subtree because its estimated error is lower (1.53). Note that error estimates are only estimates; generally, if the error difference between two options is less than twice their mean standard deviation, then statistically the errors are not different.

2. They reduce the risk of making a mistake by averaging the votes made by the options below. Every option leads to a subtree that can be thought of as an "expert." The option node averages these experts' votes. Such averaging can lead to a better classifier with a lower error rate.

   In the cars dataset, shown in Figure 12-1, the root node has an estimated error rate of 0.76%, which is lower than any of its children! Note that while brand might seem like a "giveaway" attribute for this task, the training set might not contain all brands (in fact, it does not contain all of them). For an unseen brand, the Decision Tree guesses the majority class (U.S.) and makes two errors. However, when there are other options, they are averaged, and, indeed, the error is reduced.



:
Subtree weight:392.00, test-set error:0.76+-0.76, test-set weight:131.00, purity:16.22

**Figure 12-1** Option Decision Tree for the Cars Dataset

Option Trees, however, have two disadvantages:

1. The time necessary to build an Option Tree under the default setting is about 10 to 15 times longer than that needed to build a Decision Tree.
2. The Tree Visualizer file that is created is more complex, containing 10 to 15 times as many nodes.

Run the Option Tree inducer on your dataset to determine whether the advantages in comprehensibility and error rates justify the longer induction time. You might gain additional insight as to which attributes to remove or use when building a Decision Tree.

## Inducing Option Trees

An Option Tree classifier is induced (generated) automatically from data. The data, which is made up of records and a label associated with each record, is called the *training set* (see Chapter 10, "MineSet Inducers and Classifiers").

## File Requirements

The Option Tree inducer requires a training set, as described in the "Training Set" in Chapter 10. Files are generated by extracting data from a source (such as a MineSet ASCII or binary file, or a table in an Oracle, INFORMIX, or Sybase database). To apply the generated classifier, you should have a dataset of records with the attributes used by the classifier, except that the label need not be present.

## Running the Option Tree Inducer

There are two ways to run the Option Tree inducer:

- From the Tool Manager.

  Connect to the server and select a data source (see "Choosing a Data Source" in Chapter 3). Enter the filename. For the example shown here, the filename entered would be */usr/lib/MineSet/data/cars.schema* as the filename. You'll see several attributes in the Data Transformation panel. Verify that *origin* is shown as the discrete label. Select the Option Tree inducer, and ensure you have selected the *Classifier & Error* mode. To run the Inducer, click *Go!*.

- From the command line.

  To induce an Option Tree classifier from the command line, refer to Appendix I, "Command-Line Interface to MIndUtil: Analytical Data Mining Algorithms."

## Configuring the Decision Tree Inducer Using the Tool Manager

To access the options for configuring the Option Tree inducer, select the Mining Tools tab on the Data Destination panel (Figure 12-2). From the tabs at the right, select Classify. Ensure that the inducer you select is Option Tree. Your selections in the Mode and Inducer menus determine the options available in the Further Inducer Options menu (Figure 12-3). After you have made your selections in these menus, click *Go!* to run the inducer, which, in turn, creates the classifier.

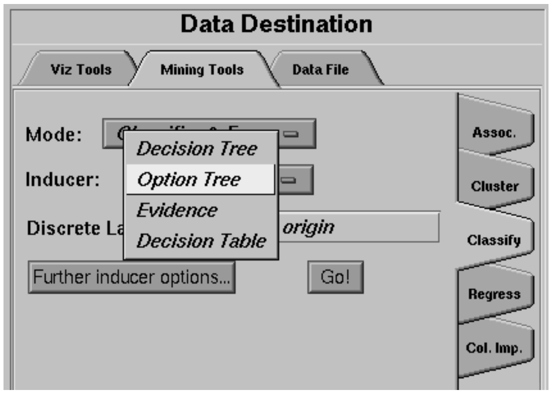


**Figure 12-2** Data Destination Panel in Tool Manager Showing Classifiers

### Discrete Labels

The Discrete Labels menu provides a list of possible discrete labels. Discrete attributes (binned values, character string values, or a few integers) have a limited number of values. You should select a label attribute with few values; for instance, two or three (see “Training Set” in Chapter 10). If there are no discrete attributes, the menu shows *No Discrete Label*, and the *Go!* button is disabled. You then must create a discrete attribute by binning or adding a new column using the Tool Manager’s Data Transformations panel.

## Parallelization

If you have installed the multiprocessor version of MineSet, it is possible to compute tree-based algorithms in parallel whenever a branch contains over 1000 records. Each node on the tree estimates the best possible split on the corresponding level, and these tasks are performed in parallel. The maximum number of threads that a program can spawn is determined automatically by default. You can control the number of threads changing the parallelization mode in the Preferences panel of Tool Manager (see "The File Menu" in Chapter 3). Parallelization may cause memory fragmentation, causing the largest data sets that can be computed in parallel to be smaller than the largest data sets that can be computed on a uniprocessor.

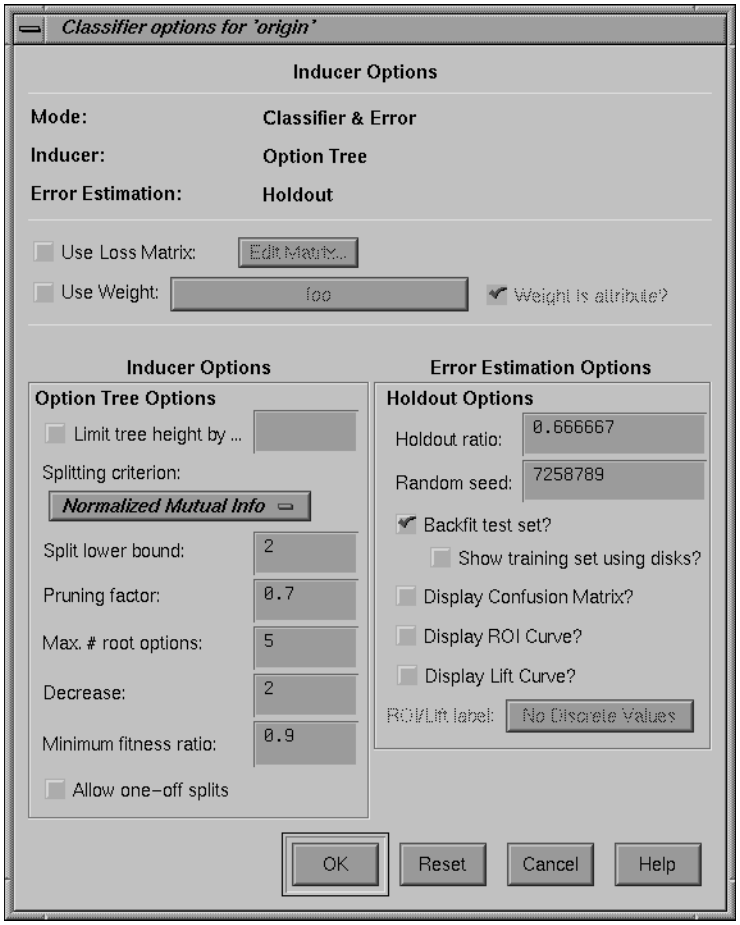
## Classifier Name

The generated classifier is named with the prefix of the session filename (as determined in Tool Manager) with the suffix *-odt.class*. By default, all classifiers are stored on the server in the *file_cache* directory, which defaults to *mineset_files*. These classifiers can be used for future classification of unlabeled records; that is, they can be used to predict the labels for unlabeled datasets (see "Applying a Model" and "Backfitting in Error Estimation" in Chapter 10).

## Option Tree: Further Options

Selecting Further Classifier Options causes the Further Inducer Options dialog box to appear. This dialog box consists of four panels:

- The top panel indicates the choices you made in the Tool Manager's Data Destination panel.
- The second pane from the top lets you set the loss matrix and the weight attribute. See "Loss Matrices: Not All Mistakes Were Created Equally" and "Record Weighting: Not All Records Were Sampled Equally" in Chapter 10.
- The bottom-left panel lets you specify further Inducer Options.
- The bottom-right panel lets you specify the Error Estimation Options (unless the mode you chose in the Data Destination panel was Classifier Only, in which case this area is empty). The options shown in this panel depend on the type of Error Estimation you chose (see "Error Estimation" in Chapter 10).



Inducer Options

Mode: Classifier & Error

Inducer: Option Tree

Error Estimation: Holdout

□ Use Loss Matrix:

□ Use Weight: foo ☑ Weight is attribute?

Inducer Options

Option Tree Options

□ Limit tree height by ...

Splitting criterion: Normalized Mutual Info

Split lower bound: 2

Pruning factor: 0.7

Max. # root options: 5

Decrease: 2

Minimum fitness ratio: 0.9

□ Allow one–off splits

Error Estimation Options

Holdout Options

Holdout ratio: 0.666667

Random seed: 7258789

☑ Backfit test set?

□ Show training set using disks?

□ Display Confusion Matrix?

□ Display ROI Curve?

□ Display Lift Curve?

ROI/Lift label: No Discrete Values

**Figure 12-3** Further Inducer Options

### Option Tree Inducer Further Options

To fine-tune the Option Tree induction algorithm, you can change any of the options for Decision Trees described in Chapter 11. In addition, the following new options are provided (see Figure 12-3).

- Max # root options

  This integer, which defaults to 5, restricts the maximum number of options that may be created at the root. While the inducer might not allow this number of options because other attributes are inferior, many natural datasets will have many good attributes that could be chosen.

- Decrease

  This integer, which defaults to 2, defines the amount by which the number of options decreases at every level. With the default of 5 for *Max # root* options, it implies that there are at most three options (5-2=3) for the second level of decision nodes. The third level of decision nodes is restricted to a single option (3-2=1). Levels further down are similarly restricted to a single option.

- Min fitness ratio

  This ratio determines when to exclude attributes as options. When the inducer gives a fitness score to each attribute, it chooses the best attribute as well as other attributes that might also be good as options. The fitness ratio determines how good those other options must be, to be chosen. A factor value of *f* implies that to be considered an option, an attribute must rank at least *(1-f)*b*, where *b* is the score for the best attribute. A fitness ratio of 1 picks all the attributes (so the limiting options described above are reached if there are attributes on which to split). A fitness ratio of 0 causes a regular Decision Tree to be created (no option nodes).

The time to induce an Option Tree is closely related to the number of option nodes created. Because option nodes usually are created near the top (where they are most useful for both comprehensibility and error reduction), a good approximation for the time to induce an Option Tree is: the number of options created that have no children options times the time to build a Decision Tree. Under the default setting, the root node can have up to five options, and each child can have up to three options. The total options then can be up to 15 (3 times 5). If the option Max # root options is increased to 6, the number of options then is limited by 48 (6*4*2); if it is increased to 7, the number of options is then limited by 105 (7*5*3). Keeping the Max # root options to 5, but changing the decrease to 1, limits the options by 120 (5*4*3*2). The expected induction time for the last example, thus, is two orders of magnitude longer than for a regular Decision Tree. Decreasing the Min fitness ratio option usually results in fewer options than the limiting factor, thus reducing induction time.

## Working in the Tree Visualizer’s Main Window

The Tree Visualizer’s main window shows the Option Tree. The navigation is the same as for decision trees. One feature that is very useful for option trees is clicking the right mouse button on an option node. This presents the list of children, which are the options.

Note that:

- The left-most option would have been the only option chosen by the Decision Tree inducer. As you go right, the options are ranked in decreasing order by the fitness scoring. Sometimes, it is interesting to see that the fitness scores do not necessarily match the test-set error shown. This is expected, as the inducer is using a non-perfect scoring function. The test-set estimate also has natural variability: the larger the test-set, the more accurate the estimate.
- The option node can have a different error rate than every one of its children. Because the option node averages the children’s predictions, its error rate can be different. In some cases, its error is strictly lower than that of every child, showing that averaging helps.
- The distribution of instances (shown in bars) at every child of an option node is exactly the same as that of the option node itself. This is because there was no decision made by the option node: options are being presented as children.

## Sample Files

The following examples show cases in which the Option Tree inducer can be useful. Each of these examples is associated with a sample data file provided with MineSet. By running the inducer, you can generate the *-odt.treeviz* files described below. The text describing the scenario and goal for each task is described in “Sample Files” in Chapter 11. Here we describe the specific advantages and disadvantages of Option Trees for several of the example datasets.

**Note:** The data files, which have a *.schema* extension, are located in */usr/lib/MineSet/data* on the client workstation. The classifier visualization files, which have a *-odt.treeviz* extension, reside on the client workstation in */usr/lib/MineSet/treeviz/examples*.

### Churn

The Option Tree for this dataset shows that total day charge, total day minutes, and customer service calls are all good attributes for the root: they all have approximately the same estimated error rate. You can choose to fly down to one subtree or another, based on your preferences and understanding of the data. Note that while the right subtree starts with customer service calls, the second test is on total daily charge or total daily minutes (as the root's left option). However, because a split already occurred on an attribute, the thresholds are different.

### Origin of Cars

The Option Tree for this dataset shows several good attributes for the root, including: cubic inches, cylinders, weight lbs, mpg, and brand. Note that the root has a lower estimated error rate than any of the children.

### Iris Classification

This is an example where Option Trees seem to be performing worse than Decision Trees. The root for the Decision Tree shows 6% error and the root for the Option Tree shows 8% error, so it seems that Option Trees perform worse. Be cautioned about making inferences regarding the error rates:

- The standard deviation of the error estimate is fairly high: 3.88% and 3.39%. A rule of thumb in statistics is that if the difference is less than two standard deviations, the difference is not statistically significant at the 95% confidence level. A difference of 2% is not larger than even a single standard deviation; hence, the classifier error rates are not statistically different at the 95% confidence level
- For small files (Iris has 150 records), different random seeds give different results. For example, changing the seed to 3 improves the Option Tree classifier's error from 8% to 4% without changing the Decision Tree classifier's error rate (remember to reset the seed). This does *not* imply that a more accurate classifier has been generated, rather that the error estimate is not stable. Because only 50 records are used for testing, each mistake is 2%. The difference between 4% and 8% is making two more mistakes.

- For small files (Iris has 150 records), use the “Estimate Error” option in MineSet. It results in better estimates that have narrower confidence intervals. When you run this mode, the status window shows that the Decision Tree classifier has an estimated error of 4.67% +/- 1.73%, and the Option Tree classifier has an estimated error of 4.00% +/- 1.61%. The difference is not significant in this case either, but the Option Tree is slightly superior.
- Even if the error rate is higher for Option Trees, they might be (and usually are) better at assigning probability estimates. For this dataset, the estimated mean squared error for Decision Trees is 3.94; for Option Trees it is 3.67 (although the difference is not significant at the 95% confidence level).

### Mushroom Classification

The Option Tree for this dataset shows that all five options chosen at the root have zero error rate estimates. Looking at the result, you might prefer the left option (bruises) because it is as accurate but is easier to measure than odor (the root test of the induced Decision Tree). You might want to remove odor and gill size, then build a regular Decision Tree that turns out to be just as accurate (0% estimated error rate).

Note, however, that removal of a root option to have a sibling option selected by the Decision Tree might not necessarily result in the same accurate classifier that is shown in the Option Tree. The removed attribute might have been used lower down in the tree. For example, removing brand from the cars dataset significantly increases the error rate, even though four out of five options do not use it at the root.

### Party Affiliation

This dataset behaves very similarly to the Iris dataset. The Option Tree has the same error rate as the Decision Tree. Under “Estimate error,” the cross-validated estimate shows that it is slightly better than the Decision Tree (but not significantly so at the 95% level) both on error rate and on mean squared error.

### Breast Cancer Diagnosis

The error rate for Option Trees is slightly lower than that for Decision Trees, both for *Classifier & Error* and for *Estimate Error*; however, the difference is not significant (at 95%).

### Hypothyroid Diagnosis

The error rates for this dataset are very low (less than 1%), but this is because most people who were tested for hypothyroid (95%) did not suffer from it. If we use a loss matrix that attempts to avoid false negatives (by penalizing by 100 a prediction of negative when the actual value is hypothyroid), we can see that the loss for Option Trees is significantly lower than that of Decision Trees: 182 versus 523 (total), or 0.17 versus 0.5 (per record). This difference is significant at the 95% confidence level.

### DNA Boundaries

For this dataset, the Option Tree is slightly more accurate than the Decision Tree; however, looking at the root options, you might notice that it chooses *left 1,2*, and *right 1,2,5*. Given the background knowledge that attributes closer to the boundary can be more important, you might want to exclude the option split on *right 5.* After updating the maximum number of root options to 4 (down from 5), the error rate increases from 5.65% to 6.59%. This might be surprising, given that the root no longer uses *right 5* as an option; another effect of changing the number of root options from 5 to 4 was to also reduce the number of options that appear further down the tree (because of the decrease parameter). This caused the individual error rates for each of the other 4 subtrees to increase. Still, the option tree's error rate is significantly better (at the 95% confidence level) than the Decision Tree error rate of 7.06% +/- 0.79%.

*Chapter 13*

# Inducing and Visualizing the Evidence Classifier

This chapter discusses the features and capabilities of the Evidence Classifier and Visualizer. It provides an overview of this classification tool as well as the inducer that generates it. It describes the ways of invoking this tool. It then explains the Evidence Visualizer's functionality when working with the

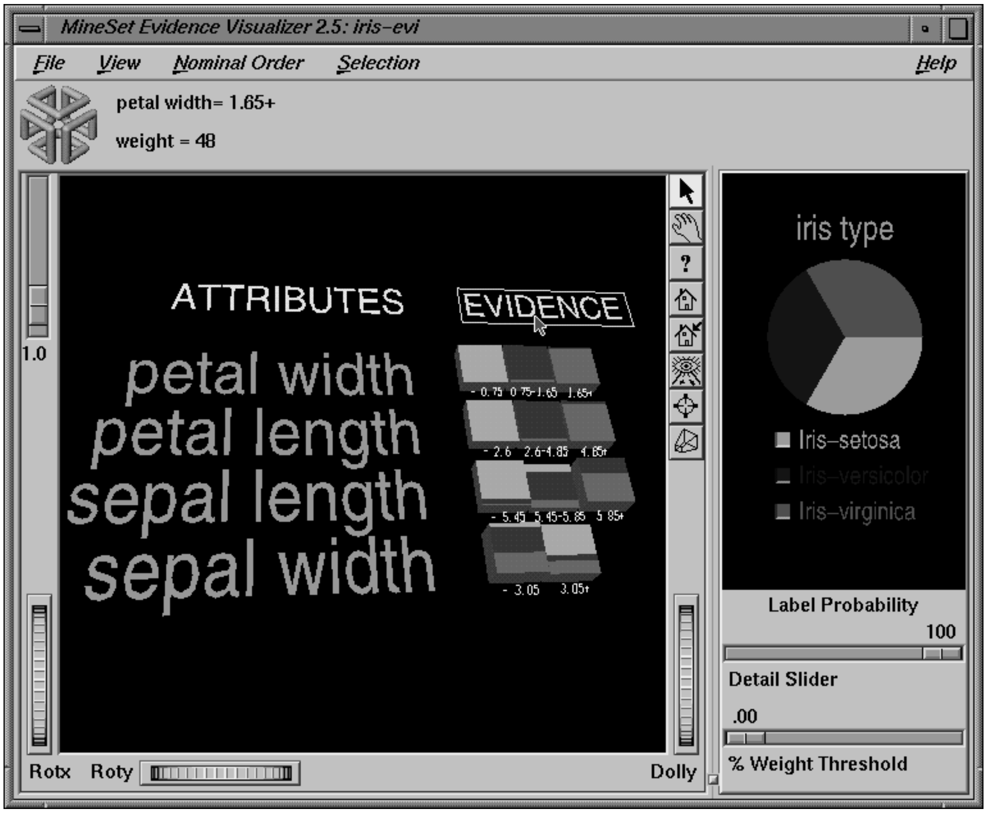
- Label Probability Pane
- Main Window

Finally, it lists and describes the sample files provided for this tool.

**Note:** It is assumed that you have read Chapter 10, "MineSet Inducers and Classifiers," before proceeding with this chapter.

## Overview

The Evidence Classifier assigns each record in a dataset to a class. The Evidence Visualizer displays the structure of an evidence classifier (Figure 13-1). The visualizer can help you understand the importance of specific attribute values for classification. Also, it can be used to gain insight into how classification is done, as well as to answer "what if" questions.



petal width= 1.65+

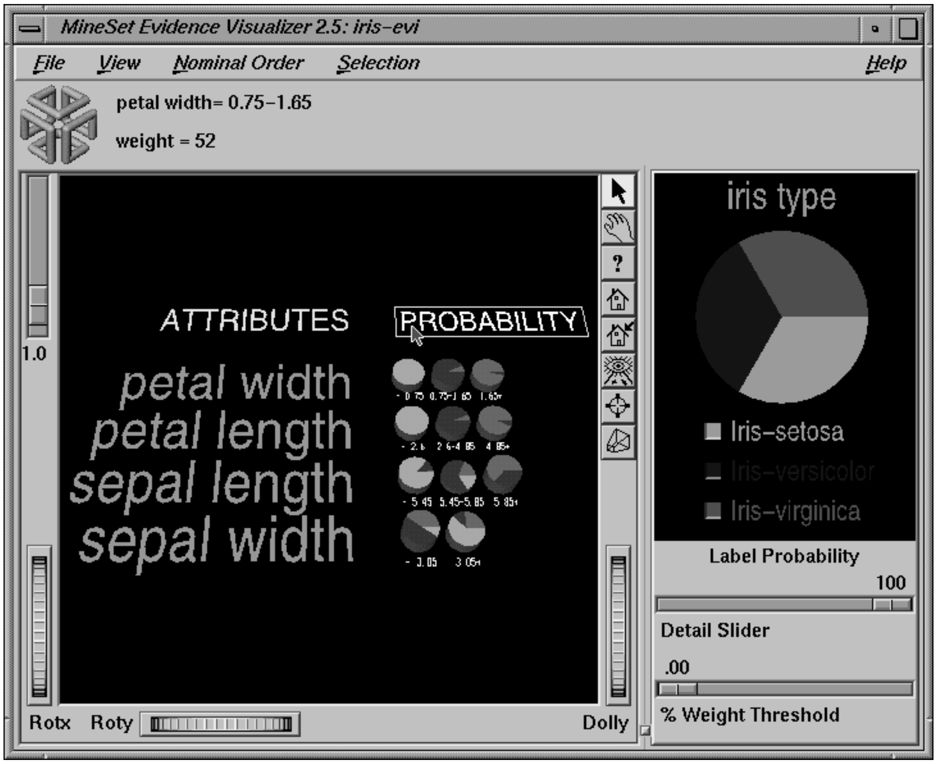
weight = 48

Label Probability 100

Detail Slider .00

**Figure 13-1** The Evidence Visualizer Applied to the Iris Dataset

The Main Window (left) contains rows of cake charts, pie charts, or bars for each attribute used by the classifier. Initially rows of cake charts are shown (as in Figure 13-1). A cake chart resembles a pie chart in that it shows proportions, but it is square with rectangular slices. To toggle between cakes, representing evidence, and pies, representing probabilities, click on the boxed title “Evidence,” and the display shown in Figure 13-2 appears. To characterize a particular class label select one of the values in the Label Probability Pane (right).



petal width= 0.75–1.65

weight = 52

Label Probability 100

Detail Slider .00

% Weight Threshold

**Figure 13-2** Evidence Visualizer Showing Probabilities

There is one chart or bar for each discrete value of the attribute. In the case where the attributes are not discrete, the continuous range has been discretized (binned) in a way that maximizes the differences between adjacent charts. A chart's height is proportional to the weight of records having that attribute value. (If no weight attribute is set, the height represents the number of records.) If no filtering is done, the sum of the chart heights for every row is the same because it is equal to the total weight of the dataset.

The height of the graphical objects can be scaled to exaggerate the differences between the charts. You can adjust a Detail slider in order to reduce the number of attributes shown starting with the ones that are less useful for classification.

By adjusting the percent weight threshold, all values having counts below a certain percentage of the total are filtered out.

The kinds of questions you might answer by using the Evidence Visualizer are as follows:

- What is the likelihood that a new record, for which you know only the values for a few attributes, has a certain label?
- Which values of which attributes are the most useful for classifying the label?
- What is the distribution of records by attribute values?
- What are the characteristics of records that have a certain label?
- What is the probability that an attribute takes on a certain value given that it has a specific label value?

The *prior probability* for each class label is depicted in the pie chart in the Label Probability Pane, on the right of the screen. The prior probability for a class label is the probability of seeing this label in the data for a randomly chosen record, ignoring all attribute values. Mathematically, this is the number of records with the class label divided by the total number of records.

The *conditional probabilities*, depicted by cake charts in the Main Window on the left of the screen, show the relative probability of each attribute value given (conditioned on) each label value. The size of a cake slice indicates the amount of evidence the classifier adds to the prior probability after taking into account a given attribute value in a record. If the size of the slices are equal, the value is irrelevant, and the classifier adds the same amount of evidence to all classes.

The probability distribution for each value, depicted by pie charts representation in the Main Window on the left of the screen, show the proportion of records in each class considering only records having that particular value. This distribution is arrived at by multiplying the conditional probabilities for the value by the prior probability, then normalizing so that they sum to one. These probabilities are precise for the data given (Figure 13-2). You may toggle between the cakes and pies representation by clicking on the boxed title “Evidence” or “Probabilities” in the scene.

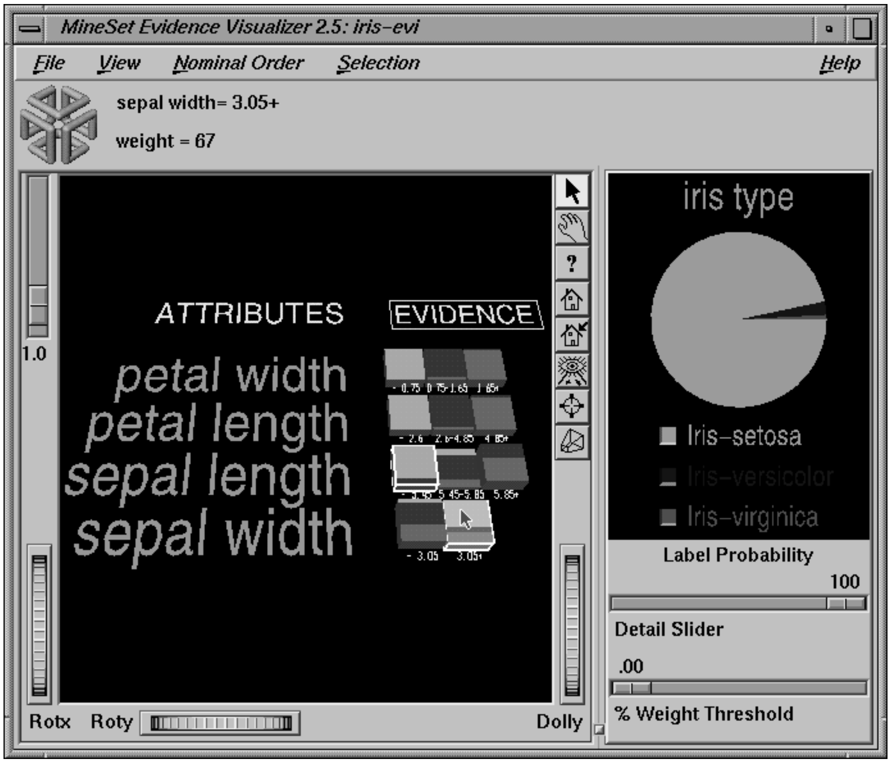
By default, values of nominal attributes are sorted by the size of the slices corresponding to one of the classes. This aids in identifying important values. If the label is a binned attribute, the class that is the highest bin is used. If the label is nominal, then the class with the largest slice in the prior probability pie is used. If a particular class is selected, and then a sort by label probability is requested, the selected class is used for determining the ordering. Alternatively, the values of the nominal attributes can be sorted alphabetically or by weight. Binned attributes never change their ordering.

Technically, the slice of the chart represents the normalized conditional probability of an attribute value A, given the class label L. The conditional probability, P(A | L), is the probability that a random record chosen only from records with label L takes the value A. Under the default settings, the probability is computed based on record weights. For example, P(0.75 < petal width < 1.65 | iris-versicolor) is 91.6, because there are 36 records with label iris-versicolor, and 33 of them have a petal width in this range.

The Evidence Inducer, sometimes called Naive-Bayes (or Simple Bayes), builds a model that assumes the probabilities of each attribute value are independent given the class. For example, this assumes that the four attributes (sepal length, sepal width, petal length, and petal width) are independent for each class of iris (iris-setosa, iris-versicolor, and iris-virginica). While this simplistic model is rarely true, the model is excellent for initial explorations of data and its classification prediction performance is very good in practical applications.

Each attribute value, or range of values, (for binned continuous attributes), defines exactly one chart, which, in turn, gives the conditional probabilities for each class label. To classify a given record, one computes the probability of each class by multiplying its prior probability by the appropriate conditional probability from each row in the matrix. The final product gives the relative probability for each class and the highest value is the predicted class. If an attribute has an unknown value, it is ignored. These NULL values are represented by charts that are slightly offset from the rest of the charts and are on the left. For example, stalk root in Figure 13-5 has a null value.

This process of classification can be done interactively using the Evidence Visualizer. Simply select all the values for the attributes that you know. The probability pie on the right changes to show the distribution you would expect, given the attribute values you selected on the left. For example, selecting the chart for sepal length < 5.45 inches and the chart for sepal width > 3.05 inches shows that an iris with these characteristics belongs almost certainly to the class iris-setosa (see Figure 13-3).The behavior is the same whether you are using the cake, pie, or bar mode.



sepal width= 3.05+

weight = 67

Label Probability

100

Detail Slider

.00

% Weight Threshold

**Figure 13-3** Selecting *sepal length* < 5.45 and *sepal width* > 3.05 Using the Iris Dataset

If the classes listed under the pie chart on the right are not numerical, they are shown in order of slice size. The class with the largest probability is at the top. As values on the left are selected, this order changes to reflect the changing probability pie. If the label is a binned attribute, the values are not reordered, and colors are assigned according to a continuous spectrum: the highest bin is red; otherwise, random colors are used.

For some combinations of selected values, the probability pie on the right turns completely gray. This occurs when the values selected are contradictory according to the model. For example, in iris.eviviz there are no iris flowers that have petal width <.75 inches and petal length > 4.85 inches. Thus, selecting the two charts on the left representing these two values results in a gray chart on the right (see Figure 13-4).

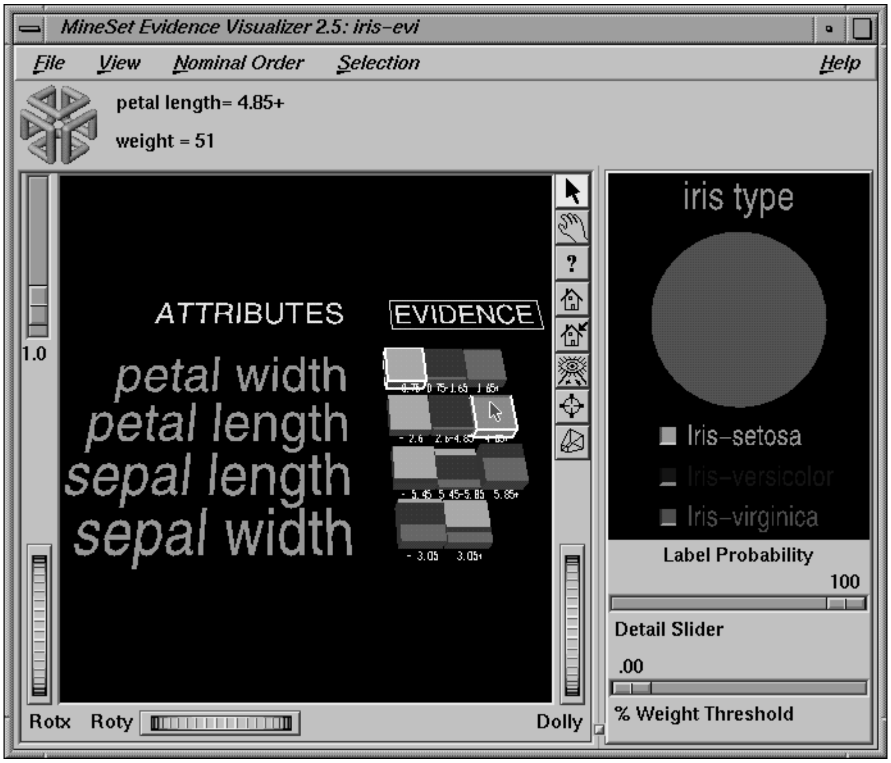
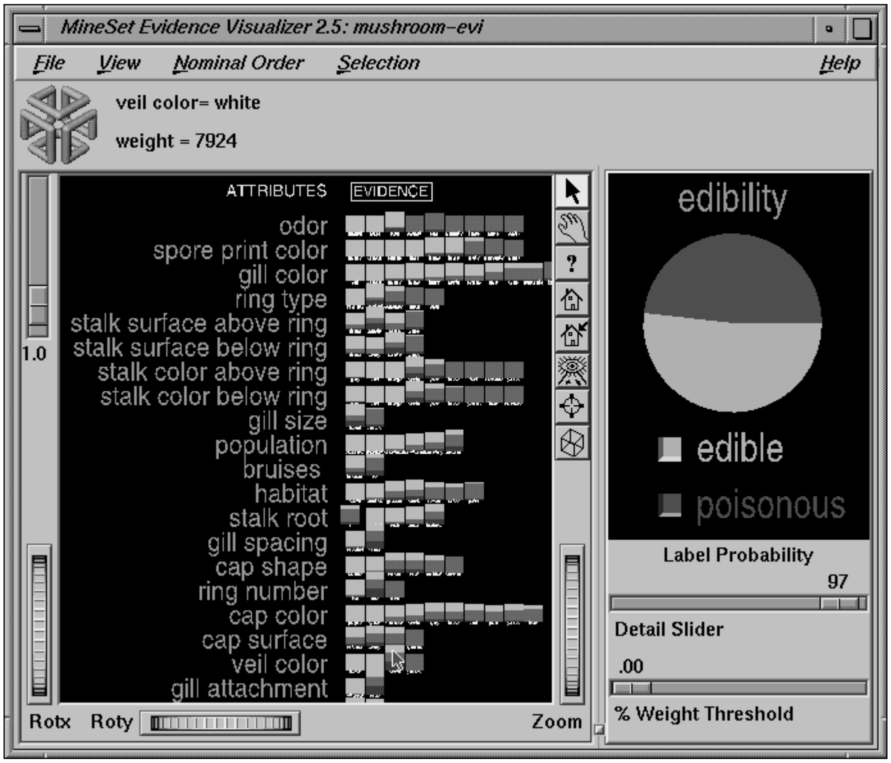


**Figure 13-4** Selecting Two Contradictory Pies Results in a Gray Pie on the Right

You can eliminate the possibility of getting a grey pie by using the Laplace correction option (see "Evidence Inducer Options" on page 402). If Laplace correction is not used, clicking more than one chart on the left yields exact posterior proportions on the right. After selecting charts with more than one attribute on the left, the posterior probability pie might not reflect exactly the true proportions in the original data; however, it is a good estimate. Laplace correction can be toggled on or off from within the tool by checkmarking View > Use Laplace Correction. Even if a value for the Laplace correction was not specified in the further inducer options, a default value for it will be used if this menu item has a check mark.

Importance is a measure of predictive power with respect to a label. The Main Window provides valuable insight not only into the importance of each attribute value affecting the class value, but also into the importance of specific attribute values. For example, in the mushroom dataset (described in "Mushroom Classification" on page 426), the veil-color attribute has little importance because its attribute value usually is white (see Figure 13-5) and does not add much evidence to either class. The importance assigned to each attribute is a number between 1 and 100. It is possible to see the value at the top by selecting the attribute name in the scene.



MineSet Evidence Visualizer 2.5: mushroom–evi

veil color= white

weight = 7924

Label Probability: 97

Detail Slider: .00

**Figure 13-5** Veil-Color Attribute in the Mushroom Dataset

However, if the veil color is brown or orange, the mushroom is likely to be edible, while if it is yellow, it is likely to be poisonous. Similarly, a "test for AIDS" might not be an important attribute for determining whether a patient has a deadly disease because most people would not test positive. However, the value "positive" for this test is highly informative because most patients that test positive do have a deadly disease.

## Inducing Evidence Classifiers

The automatic induction of Evidence classifiers is a process whereby counts (or weights) are used to calculate the probabilities. Evidence classifiers are automatically induced (generated) from data. The data, which is made up of records and a label associated with each record, is called the *training set* (see Chapter 10).

The probabilities are generated using the following method:

1. All continuous attributes are discretized (binned), such that class distributions in these ranges are as different as possible. The number of ranges is determined automatically, which invokes parallelization so that attributes are binned in parallel, if the multiprocessor version of MineSet is installed on your system. The automatic binning for any attribute may be overridden by explicitly performing the binning operation in Tool Manager.
2. The prior probabilities are the proportions of each class in the training set.
3. The conditional probabilities are the probabilities of each attribute value conditioned on each class label in the training set. (The charts show them normalized for each attribute value.)

The number of charts in a row is the number of discrete ranges produced by the inducer. If there is just one range, it means that this attribute by itself was not useful in predicting the label. Initially, the prior probabilities of the labels are displayed in the Label Probability Pane.

An optional Auto Column selection mode removes attributes that are not useful or that increase the error rate.

An optional Laplace correction can be applied to the probabilities, which avoids extreme probabilities (for example, probabilities of zeros and ones). We may prefer not to assign a probability of 1 to the event “a patient tested positive for AIDS has a deadly disease.” We may want to assign a probability close to 1 (but not 1), in order to allow for errors or unrepresentative samples.

Note that the Evidence Visualizer shows the probabilities of classes. The classifier can have a Loss Matrix. In the visualization the Loss Matrix (if present) may be applied by clicking the button to the lower right of the pie in the label probability pane. The predicted class is the one with the least expected loss under the probability estimates.The Loss Matrix button will only appear if it has been specified in the *.eviviz* file (see Appendix G, “Format of the Evidence Visualizer’s Data File.”

## File Requirements

The Evidence Visualizer requires a training set, as described in “Training Set” on page 322 of Chapter 10, “MineSet Inducers and Classifiers.” Files are generated by extracting data from a source (such as a MineSet ASCII or binary file, or a table in an Oracle, INFORMIX, or Sybase database). The Evidence Visualizer data file is output as a result of running the Evidence Inducer. The format of this file, which has a *.eviviz* extension, is described in Appendix G. When starting the Evidence Visualizer or when opening a file, you must specify the data filename. To apply the generated classifier, you should have a dataset of records with the same attributes and type as those used by the classifier, except that the label need not be present.

## Running the Evidence Inducer

There are two ways to run the evidence inducer:

- From the Tool Manager

  Connect to the server and select a data source (see “Choosing a Data Source” in Chapter 3).

  From the File menu, choose Open New Data File. Log in to a server, and type `/usr/lib/MineSet/data/iris.schema` as the filename. You’ll see four continuous attributes and one discrete attribute in the Data Transformation panel. Since there is only one discrete attribute, the label option automatically shows it. Select the Evidence Inducer, and ensure that you have selected the Classifier & Error mode. To run the Inducer, click *Go!*.

  The Status window shows the progress and resulting statistics.

- From the command line

  To induce an evidence classifier from the command line, refer to Appendix I, “Command-Line Interface to MIndUtil: Analytical Data Mining Algorithms.”

## Starting the Evidence Visualizer

There are six ways to start the Evidence Visualizer:

- Run the Evidence Inducer from the Tool Manager under the Classify tab. After the inducer builds the classifier, it automatically invokes the Evidence Visualizer. See below for details about using the Tool Manager in conjunction with the Evidence Visualizer.
- Use the Tool Manager to start the Evidence Visualizer from the Visual Tools menu. (See Chapter 3 for details on the Tool Manager's functionality, which is common to all MineSet tools.)
- Double-click the Evidence Visualizer icon on your Indigo Magic desktop. The startup screen requires you to select a data file by choosing File > Open.

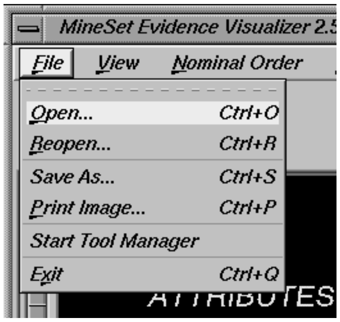


**Figure 13-6** File > Open Menu Selection

- If you know what configuration file you want to use, double-click the icon for that configuration file. This starts the Evidence Visualizer and automatically loads the configuration file you specified. This works only if the configuration filename ends in *.eviviz* (which is always the case for configuration files created for the Evidence Visualizer via the Tool Manager).
- If you know what configuration file you want to use, drag its icon onto the Evidence Visualizer icon. This starts the Evidence Visualizer and automatically loads the configuration file you specified.
- Start the Evidence Visualizer from the UNIX shell command line by entering this command at the prompt:

```
eviviz [ dataFile ]
```

Here, *dataFile* is optional and specifies the name of the configuration file to use. If you don't specify a configuration file, you then must use File > Open to specify one (see Figure 13-6).

### Options for Invoking the Evidence Visualizer

The **`-quiet`** option eliminates the dialogs that popup to indicate progress. You can enable this option permanently by adding the line

```
*minesetQuiet:TRUE
```

to your *.Xdefaults* file.

## Configuring the Evidence Inducer Using the Tool Manager

To access the options for configuring the Evidence Inducer, select the *Mining Tools* tab on the Data Destination panel (Figure 13-7). From the subsequent tabs, select *Classify*. Ensure that the inducer you select is Evidence. Your selections in the Mode menu determines the options available in the Further Inducer Options menu. After you have made your selections in these menus, click *Go!* to run the inducer, which, in turn, creates the classifier.

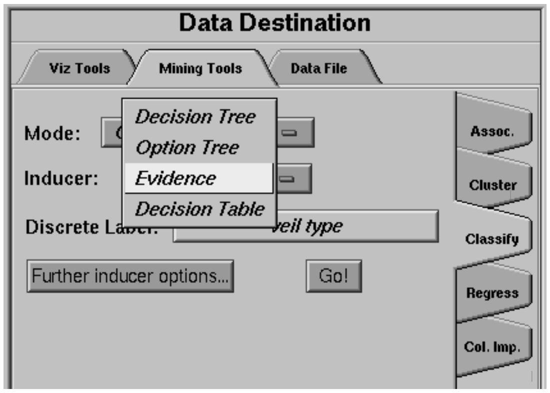


**Figure 13-7** Tool Manager With Data Destination Panel Showing Classifiers

### Discrete Labels

The Discrete Labels menu provides a list of possible discrete labels. Discrete attributes (binned values, character string values, or integers) can have a number of values. Select a label attribute (see “Training Set” in Chapter 10). If there are no discrete attributes, the menu shows No Discrete Label, and the *Go!* button is disabled. You then must create a discrete attribute by binning or adding a new column using the Tool Manager’s Data Transformations panel.

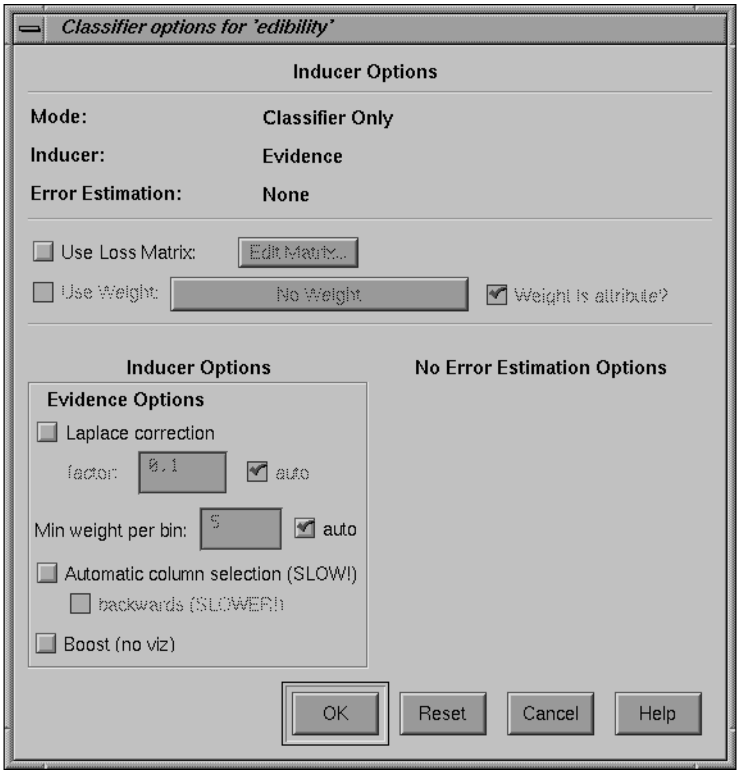
### Classifier Name

The generated classifier is named with the prefix of the session filename (as determined in Tool Manager) and the suffix *-evi.class*. By default, all classifiers are stored on the server. These classifiers can be used for future classification of unlabeled records; that is, they can be used to predict the labels for unlabeled datasets (see “The Apply Model Button” in Chapter 3).

### Refining the Inducer With Further Options

Selecting Further Inducer Options causes the Inducer Options dialog box to appear (see Figure 13-8). This dialog box consists of three panels:

- The top panel shows the choices you made in the Tool Manager’s Data Destination panel. The type of Error Estimation is determined by the model.
- The bottom-left panel lets you specify further Inducer Options.
- The bottom-right panel lets you specify the Error Estimation Options (unless the mode you chose in the Data Destination panel was Classifier Only, in which case this area is empty). The options shown in this panel depend on the type of Error Estimation you chose (see “Error Estimation” in Chapter 10).



Classifier options for 'edibility'

Inducer Options

Mode: Classifier Only

Inducer: Evidence

Error Estimation: None

□ Use Loss Matrix:

□ Use Weight: No Weight

☑ Weight is attribute?

Inducer Options

No Error Estimation Options

Evidence Options

□ Laplace correction

factor: 0.1 ☑ auto

Min weight per bin: 5 ☑ auto

□ Automatic column selection (SLOW!)

□ backwards (SLOWER!)

□ Boost (no viz)

**Figure 13-8** Classification Options Dialog Box Without Accuracy Estimate

### Evidence Inducer Options

By choosing Further Inducer Options, you can fine-tune the Evidence inducer.

- Laplace Correction

  This biases the probabilities towards the average, thus avoiding extreme numbers (such as 0 and 1). This means every chart in the Main Window has a non-zero slice for each class. The fewer the records in a bin, the more it is changed towards the average. If the Laplace correction is checked, and the factor is left empty or set to 0, an automatic Laplace correction is applied, using a heuristic that applies a factor of 1/training-set-weight.

- Set Minimum Weight per Bin

  The Evidence Inducer discretizes all continuous attributes. This option lets you define the minimum number of instances per bin. The automatic setting has a heuristic that sets this number based on the dataset size: the larger the dataset, the greater the minimum number of records allowed in the bin, and the smaller the width of the bin, in general. If your dataset is very large, you might obtain more discrete ranges than you want. To reduce the number of bins, raise this value.

- Automatic column selection

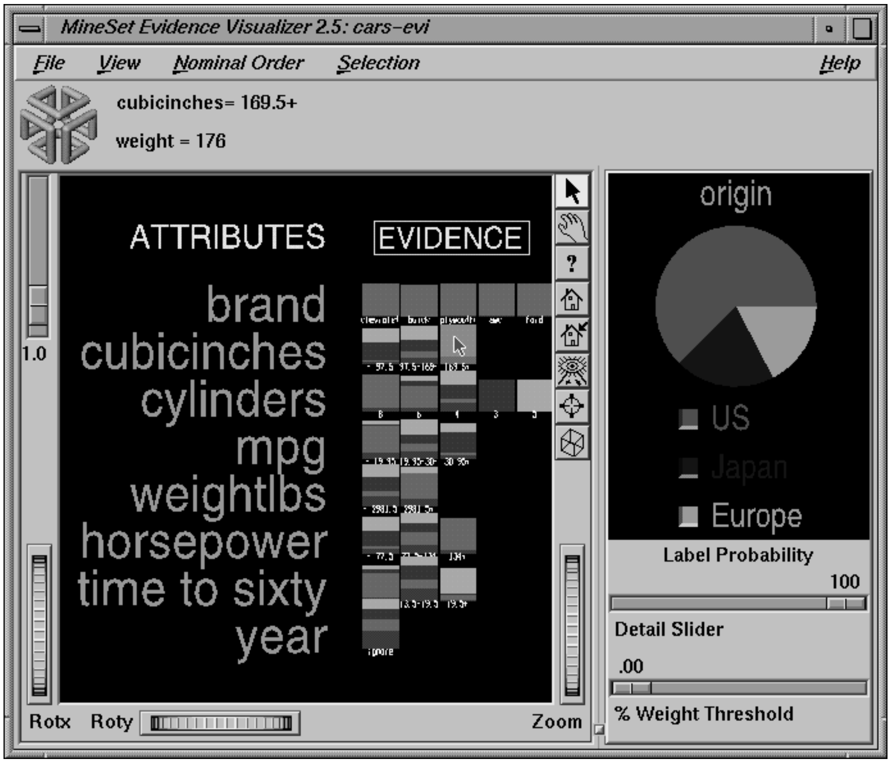
  This applies a process that chooses only those columns that help prediction the most. Because extra columns can degrade the predictive accuracy of the evidence classifier, this process searches for a good subset of the columns automatically. Only those columns found to be useful are used. This process can take a long time, especially if there are many columns. It is useful for eliminating highly correlated columns that could degrade accuracy. Automatic column selection and Boosting cannot both be enabled, as together they would take far too long to complete.

  Automatic column selection conducts a search for the best set of columns that reduce the error of the classifier. The selection of these columns is done by estimating the error of different attribute sets using the wrapper approach (see Appendix K, “Further Reading and Acknowledgments”). Each feature subset is evaluated by estimating the classifier's error using cross-validation. Columns are added or removed based on the error estimates using a best-first search mechanism. In the default mode, the search begins with an empty set of features. By selecting the *Backwards* option, the search starts with the full set of options; this is slower, since larger models are initially built.

## Working in the Evidence Visualizer’s Panes

If you started the Evidence Visualizer without specifying a configuration file, the main screen shows the copyright notice for the Evidence Visualizer. Only the File and Help pulldown menus are available. To view all menus and controls in the Main Window, open a configuration file. Use File > Open (see Figure 13-6) to see a list of configuration files.

When a valid configuration file is specified, the two panes in the main screen display graphics. For example, specifying *cars.eviviz* results in the output displayed in Figure 13-9.



cubicinches= 169.5+

weight = 176

Label Probability 100

Detail Slider .00

% Weight Threshold

**Figure 13-9** Evidence Visualizer Window for cars.eviviz

In the Main Window on the left, one row of cake charts appears for each attribute in the dataset that the classifier is using. Each chart corresponds to a value for the attribute associated with the row. In the Label Probability Pane on the right, a list of all class labels appears under a large pie chart of the prior probability distribution. Note that the color of the slices correspond to the color associated with each class label. This prior probability represented by the pie shows the proportion of data with each class label.

## Viewing Modes

Both of the Evidence Visualizer’s window panes has two modes of viewing: grasp and select.

### Viewing Modes in the Label Probability Pane

The Label Probability Pane is located on the right of the Evidence Visualizer’s Main Window. The top two buttons of those aligned vertically between the panes toggle between the grasp and select modes. Alternatively, the Esc key also toggles the viewing mode for both panes.

In grasp mode, the cursor appears as a hand that lets you pan and scale the scene’s size.

- To move the display within the pane, press the middle mouse button and drag it in the direction you want the display moved.
- To enlarge the scene, press the left mouse button, and drag the mouse downward.
- To shrink the scene, press the left mouse button, and move the mouse upward.

### Viewing Modes in the Main Window

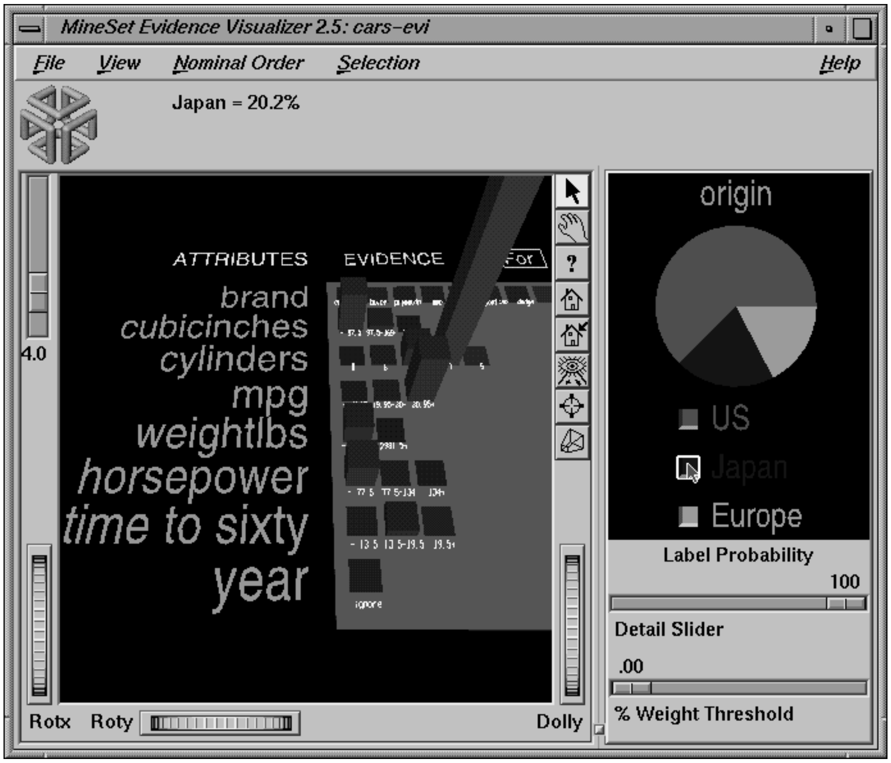
The Main Window is located on the left of the Evidence Visualizer’s display window. The top two buttons of those aligned vertically between the panes toggle between the grasp and select modes. Alternatively, the Esc key also toggles the viewing mode for both panes.

In grasp mode, the cursor appears as a hand, so you can pan, rotate, and scale the scene’s size. (The Label Probability pane contains only 2D geometry; thus, rotation is disabled.)

- To rotate the display, press the left mouse button and move the mouse in the direction you want.
- To move the display within the pane, press the middle mouse button, and drag it in the direction you want the display moved.
- To enlarge the viewpoint, simultaneously press the left and middle mouse buttons and move the mouse downward. To shrink the viewpoint, simultaneously press the left and middle mouse buttons, and move the mouse upward. This is equivalent to the functions provided by the Dolly thumbwheel.

### Selecting Items in the Label Probability Pane

In select mode, the cursor appears as an arrow. If you then click the button to the left of one of the class labels, a white box appears around the button next to the label (see Figure 13-10). The size of that slice (the probability of predicting that label value) appears in the text output line at the top. To deselect a class label, click on it again. Moving the mouse over the button next to a class label, in select mode, causes the size of that slice (in percentage terms) to appear in the output line at the top.



Japan = 20.2%

Label Probability 100

Detail Slider .00

% Weight Threshold

**Figure 13-10** Label Value “Japan” Selected Using the Cars Dataset

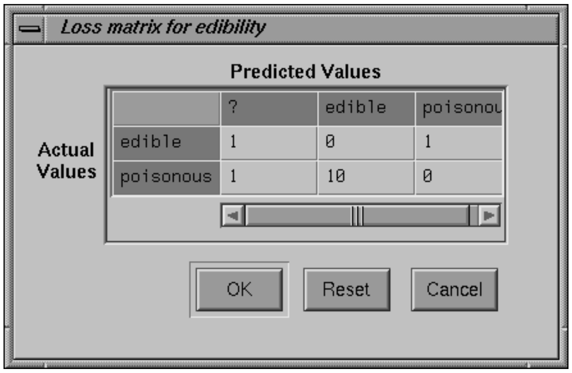
If no label is selected, the Main Window on the left displays cake or pie charts (see Figure 13-10).

If a label is selected, the representation on the left displays bar charts (see Figure 13-10). The height of each bar shows the evidence in favor of the selected label value. *Evidence for* is the negative log of the quantity one, minus the size of the slice matching the selected label, in the corresponding chart representation.

The grayness of the bars is based on the 95% confidence interval. This, in turn, depends on the weight for that value. Hence, bars that are nearly gray have low weight and a large confidence interval. The height of gray bars is not likely to be very accurate. Conversely, the height and corresponding evidence value for a fully saturated bar can be relied on because it is based on large weight, representing many records. The exact number of records (*weight*) is reflected in the text output line when that bar is highlighted.

As the default, the amount of evidence common to all the labels is subtracted. This means that the height of a bar for each value is reduced by the height representing the label for which the evidence is smallest. If you select a different label, the bars and their colors change to represent the new class label. Selecting the same label again deselects it, and the Main Window again displays the cake or pie charts. Uncheck the View > Subtract minimum evidence option if you do not want to subtract the common evidence.

If a Loss Matrix has been specified in the Further Inducer options, a button labelled *Use Loss Matrix* appears to the lower right of the probability pie. When selected (the default) the Loss Matrix is used to adjust the probabilities shown. The largest slice shown is the class that takes into account the Loss Matrix. To see what the probabilities would be without using the Loss Matrix, deselect the *Use Loss Matrix* button. When using the Loss Matrix, a gray slice may be present because there was a column for predicting null when you edited it. If the gray slice is the largest slice, the classifier predicts null.



Predicted Values

| Actual Values | | ? | edible | poisonou |
|---|---|---|---|---|
| | edible | 1 | 0 | 1 |
| | poisonous | 1 | 10 | 0 |

**Figure 13-11** Loss Matrix to Avoid Predicting Poisonous Mushrooms as Being Edible

Figure 13-11 shows a Loss Matrix that has been edited to reduce the likelihood of predicting a mushroom edible when it is really poisonous. Figure 13-12 shows the initial state of the Label Probability pane for the resulting Evidence Visualizer. Normally the prior probability on the right shows slices of almost equal sizes for edible and poisonous mushrooms. Using this Loss Matrix, however, we csn be much more cautious about predicting that a mushroom is edible.

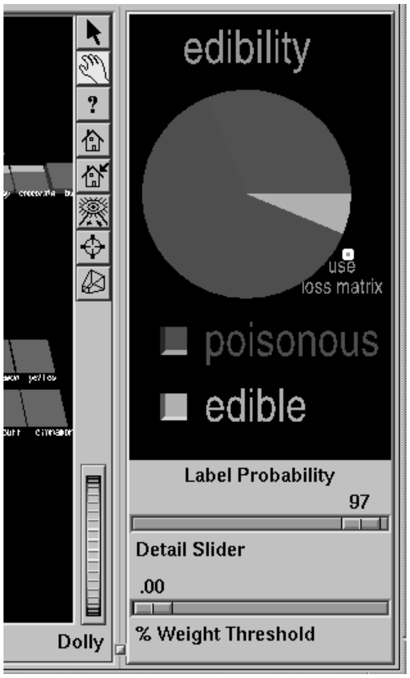


**Figure 13-12** Loss Matrix Applied to Probabilities in the Label Probability Pane

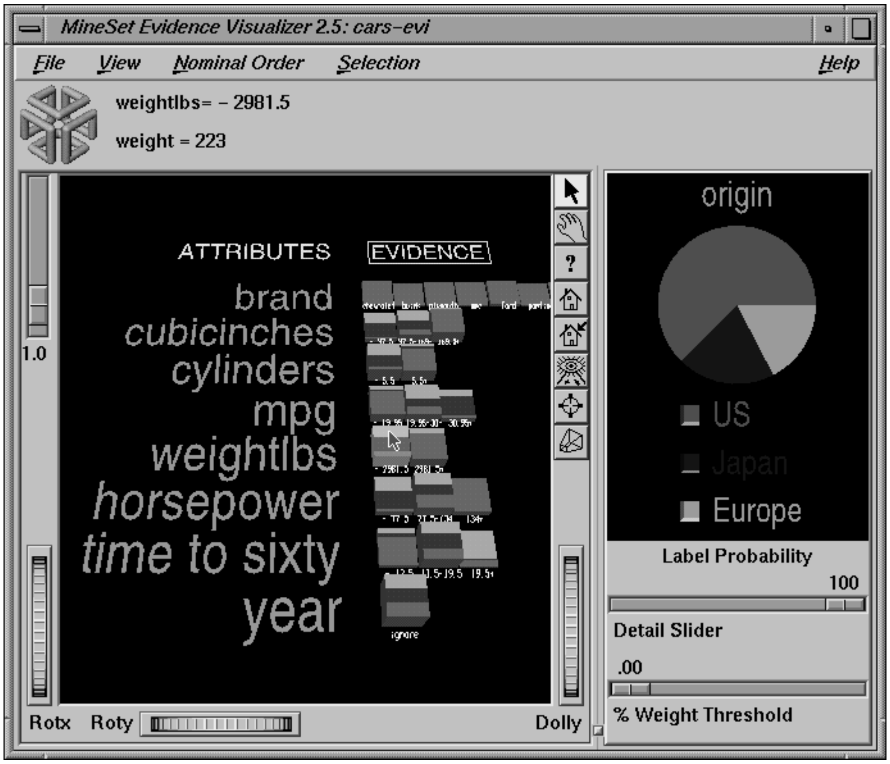
### Selecting Items in the Main Window

In select mode, the cursor appears as an arrow. You can highlight an object (either a pie chart or a bar) by moving the cursor over that object. Information about that object then appears above the Main Window. The information is displayed as long as the cursor is over the object.

- If the object is a pie chart, then the message takes this format:

  ```
  <attribute name>: <value or range>
  weight = <weight>
  ```

  Here, *weight* is the total weight of the data points that fall in that range or have that value for that attribute (see Figure 13-13). The chart height is proportional to this number. Unless record weighting is used, the weight shows record counts.



weightlbs= – 2981.5

weight = 223

**Figure 13-13** Pie Charts With the First Binned Range of weightlbs Highlighted

- If the object is a bar, then the message takes this format:

  ```
  (<attribute> = <value>) ==> Prob(<selected label>) = x%
  [low%-high%]      Evidence=z
  <selected label> ==> Prob(<attribute> = <value>) = y% [low%-high%]
  weight = <weight>
  ```

  See Figure 13-14.

  Here, *x* is the probability that a record has the selected label given that it has the highlighted attribute value. The bracketed range, [low%-high%] gives the 95% confidence interval. Similarly, y% is the probability that a record has the highlighted attribute value given the selected label (see Figure 13-14). Note that the height of the bar shows evidence, not probability. The amount of evidence, z, is directly related to the bar heights. Evidence can be summed in order to determine which class is predicted (unlike probability, which must be multiplied). *Weight* is the weight of data points having that value.

  Technically, *evidence for* is defined as

  $$-\log \left[ 1 - \frac{P(A \mid L)}{\sum_{i=1}^{N} P(A \mid L_i)} \right]$$

  while *evidence against* is defined as

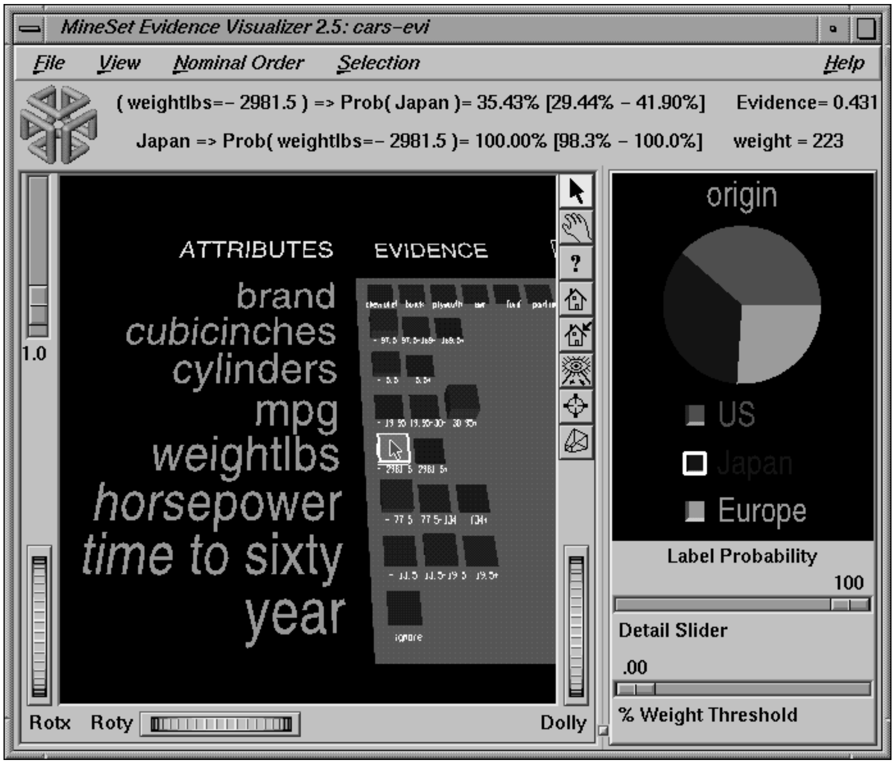
  $$-\log \left[ \frac{P(A \mid L)}{\sum_{i=1}^{N} P(A \mid L_i)} \right]$$

  A is the attribute value, L is the selected label value, and N is the number of label values. When computing the bar heights, a very small number is added inside the brackets of the above expressions to prevent the bars from becoming infinitely tall. The word “for” or “against” in the Main Window has a box around it to indicate that it may be clicked on. Click on the box to toggle the representation.

  The height of the gray rectangular base (on which the bars stand) represents the amount of evidence contributed by the prior probability. For example, if the label is car cylinders, there are very few three cylinder cars, so the base is low when *evidence for* is showing, and high when *evidence against* is showing. You can add to this height the height of individual bars that are on top.

  *Evidence for* can be useful in determining which values are the most helpful in predicting a particular label value.

The amount of evidence (bar height) is not derived directly from either probability shown while highlighting. Instead, the evidence depends on the conditional probability relative to the other probabilities for all the other label values according to the equation above.



MineSet Evidence Visualizer 2.5: cars-evi

( weightlbs=- 2981.5 ) => Prob( Japan )= 35.43% [29.44% - 41.90%]   Evidence= 0.431

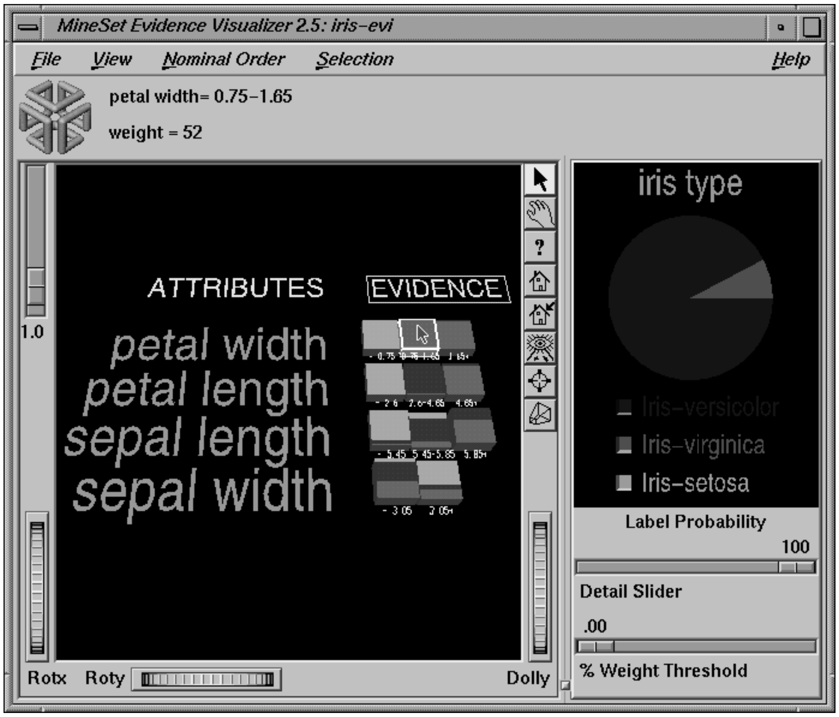
Japan => Prob( weightlbs=- 2981.5 )= 100.00% [98.3% - 100.0%]   weight = 223

Figure 13-14 Bar Chart With a Range Selected

You can also select any number of values from an attribute row by clicking the left mouse button while the cursor is over one of the attribute values. This causes the object to be drawn with a white bounding box surrounding it (see Figure 13-14). The large pie chart in the Label Probability Pane on the right changes to reflect items you select; it now shows the posterior probability, given the attribute values just selected. Note that the classes remain ordered, so the one corresponding to the largest slice is at the top of the list on the right. The Evidence Visualizer arrives at the new posterior probability distribution by multiplying the conditional probabilities for each attribute together, then multiplying this result by the prior probability and normalizing to one.

This multiplication corresponds to a conditional independence assumption. When this assumption is violated, and multiple values for attributes are chosen, the predicted class probabilities are likely to be too extreme, although the final classification might be correct. The estimated error shown in the Status window when you run the inducer can help you determine how reasonable this assumption is. If the error rate/loss is low, the assumption is reasonably robust in the domain.

Before clicking on a square chart, the Evidence Visualizer appears as shown in Figure 13-1. This shows that given no additional information, there is an approximately equal likelihood that an iris will be designated type iris-setosa, iris-versicolor, or iris-virginica. If you click a chart for petal width .75 - 1.65, the pie on the right changes to that shown in Figure 13-15. This indicates that if the petal width is between .75 and 1.65, the iris probably belongs to the class iris-versicolor. You then can select additional values to further change the distribution. The order in which you select charts or bars does not matter.

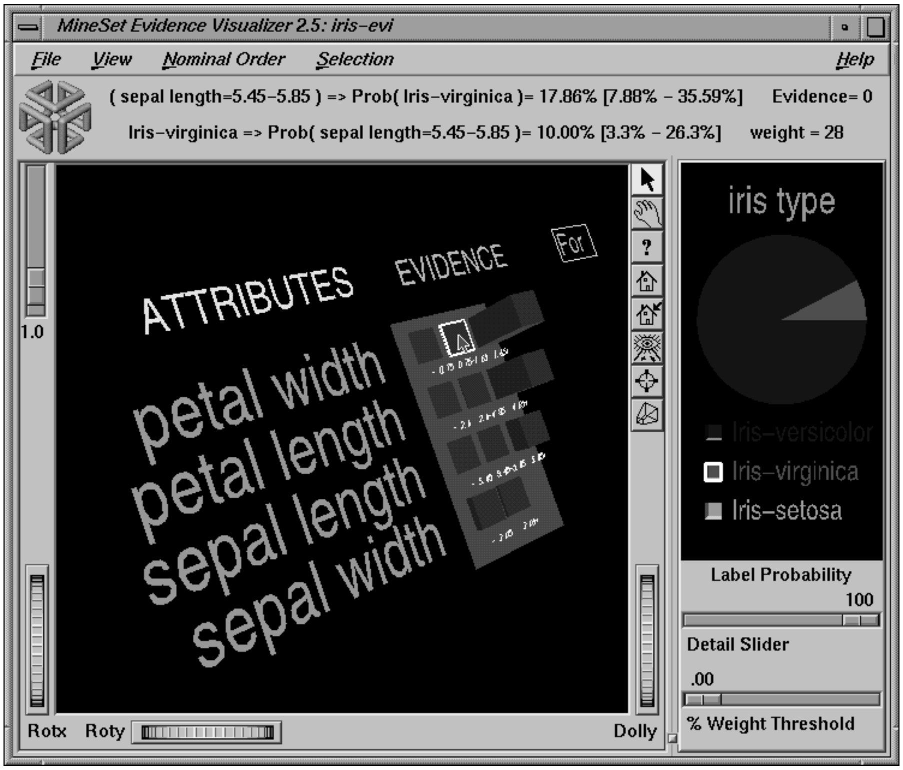


petal width= 0.75–1.65

weight = 52

**Figure 13-15** Iris Dataset With the Value petal width .75 - 1.65 Selected

When a particular label has been selected in the Label Probability Pane, the Main Window shows bars rather than cakes or pies for each value of an attribute. The title over the bars reads "Evidence For." The box around the "For" indicates that it can be selected (Figure 13-16).



( sepal length=5.45–5.85 ) => Prob( Iris–virginica )= 17.86% [7.88% – 35.59%]    Evidence= 0

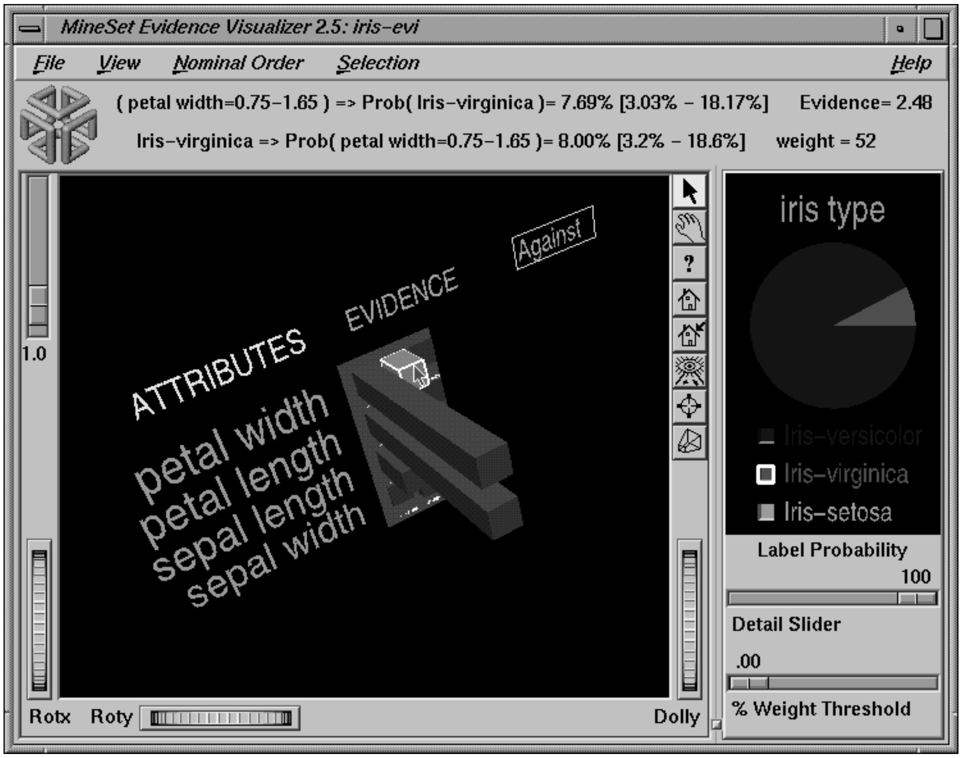
Iris–virginica => Prob( sepal length=5.45–5.85 )= 10.00% [3.3% – 26.3%]    weight = 28

Label Probability 100

Detail Slider .00

**Figure 13-16** Bars Showing Evidence For iris-virginica

Clicking the "For" in the "Evidence For" title toggles it to display "Against". As a result, the bar heights change to show evidence against the label (Figure 13-17).



MineSet Evidence Visualizer 2.5: iris-evi

( petal width=0.75-1.65 ) => Prob( Iris-virginica )= 7.69% [3.03% - 18.17%]    Evidence= 2.48

Iris-virginica => Prob( petal width=0.75-1.65 )= 8.00% [3.2% - 18.6%]    weight = 52

**Figure 13-17** Bars Showing Evidence Against iris-virginica

Selecting bars has the same effect on the large probability pie in the Label Probability Pane to the right as did selecting cakes or pies. The bar height indicates the amount of evidence for or against the selected label contributed by that selected value. Since log probabilities are used to represent evidence, the bar heights are added to accumulate evidence (whereas probabilities must be multiplied).

## External Controls

The external controls for the visualizer associated with the Decision Table classifier are the same as those for the Map Visualizer. For a description of these controls, see "External Controls" in Chapter 5.

### Sliders

The Evidence Visualizer contains three sliders: Height Scale, Detail Slider, and Percent Weight Threshold.

The Height Scale Slider (Figure 13-18), which is located in the upper left of the Evidence Visualizer, scales the height of the charts and bars. You can use this slider to magnify small differences.

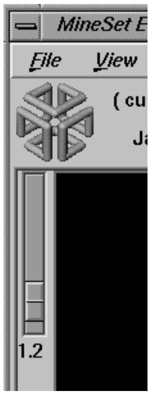


**Figure 13-18** Evidence Visualizer Height Scale Slider

The Detail Slider, located at the bottom right of the Evidence Visualizer window (Figure 13-19), filters out attributes that are not as useful for classifying the selected label. This quality, assigned a value between 0 and 100 by the inducer, is called *importance*. This measure is on an absolute scale. To understand how importance is calculated, see "Column Importance and Relation to Classifiers" on page 497. As the slider is moved to the right, attributes that fall below the requisite importance value are removed from the scene. If the attributes are sorted by importance (the default), then the ones at the bottom are the first to be removed.

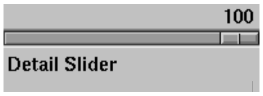


**Figure 13-19** Evidence Visualizer Detail Slider

The Percent Weight Threshold Slider, located at the bottom right of the Evidence Visualizer window (Figure 13-20), filters out values having counts less than the percentage indicated by the slider (up to a maximum of 2%). This slider helps visualize attributes that have a large number of values, many of which occur infrequently (and, hence, are not as useful). For example, if an attribute has 101 values, removing values with counts less than 1% of the total might remove all values, and must remove at least 2.

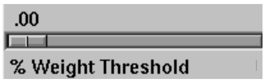


**Figure 13-20** Evidence Visualizer Percent Weight Threshold Slider.

## Pulldown Menus

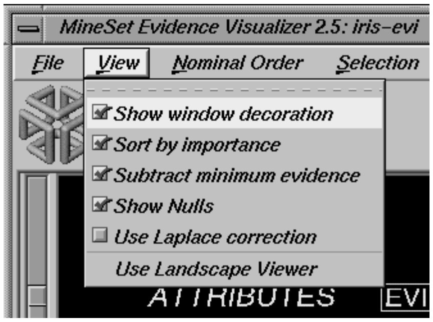
Five pulldown menus let you access additional Evidence Visualizer functions: File, View, Selection, Nominal Order and Help. If you start the Evidence Visualizer without specifying a configuration file, only the File and the Help menus are available.

### The File Menu

The File menu lets you open a new configuration file, reopen the current configuration file, save an image of a current display, send an image of the display to the printer, start the Tool Manager, or exit the Evidence Visualizer.

## The View Menu

The View menu lets you control certain aspects of what is shown in the Evidence Visualizer pane (Figure 13-21).



☑ Show window decoration
☑ Sort by importance
☑ Subtract minimum evidence
☑ Show Nulls
□ Use Laplace correction
Use Landscape Viewer

**Figure 13-21** Evidence Visualizer's View Menu

This menu contains six options:

- *Show Window Decoration* lets you hide or show the external controls around the display window.
- *Sort By Importance* lets you display the attributes sorted according to their usefulness in classifying with respect to the chosen label. If this option is turned off, then the attributes will appear in the same order they did under "Current Columns" in the Tool Manager.
- *Subtract Minimum Evidence* applies only when a label has been selected and the bars are shown. With this option on (the default), the height that is the minimum over all the label values is subtracted. This amount may be different for each value of each attribute, but for a given attribute value, the amount subtracted is constant across label values. Activating this option magnifies small differences by subtracting the least common denominator among all the label values.
- Show Nulls toggles the display of null values. Null values, if present, are shown as the first value, offset slightly from other non-Null values.
- Use Laplace Correction toggles the use of Laplace correction. If a specific Laplace correction was specified in the further inducer options dialog box, then that value gets used, otherwise a default value is provided.
- *Use Landscape Viewer* (or *Use Examiner Viewer*) switches to an alternative mode of 3D navigation. To understand navigation using the Landscape viewer see "Navigating With the Middle Mouse Button" in Chapter 5.

## The Nominal Order Menu

The Nominal Order menu lets you control how values for nominal attributes are ordered (Figure 13-22).

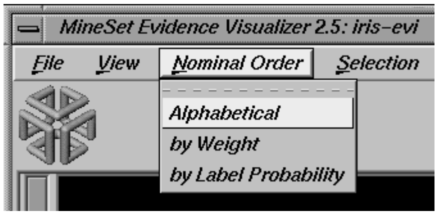


**Figure 13-22** Evidence Visualizer's Nominal Order Menu

The three choices are:

- *Alphabetical* implies values for nominal attributes are sorted from left to right, in alphabetical order.
- by *Weight* sorts values from left to right, with those having the largest number of records appearing toward the left.
- by *Label Probability* (the default) sorts the values of nominal attributes by the size of the slices corresponding to one of the classes. If the label is a binned attribute, the highest bin is used by default. If the label is nominal, then whatever class has the largest slice in the prior probability pie is used by default. If a particular class is selected, and then sort by label probability is requested, the selected class is used for determining the ordering. In all cases, if there is a NULL value, it remains at the far left.

## The Selection Menu

The Selection menu allows drill-through to the underlying data (Figure 13-23). To do a drill-through, first select some combination of values and/or a class, then chose one of the two methods of drilling-through to the underlying records.

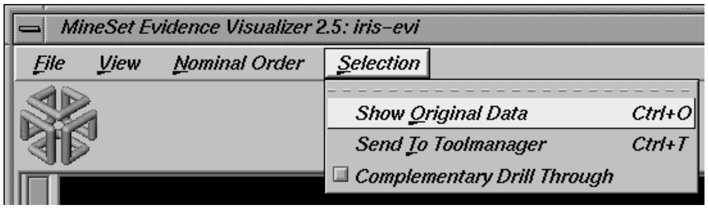

MineSet Evidence Visualizer 2.5: iris-evi
File
View
Nominal Order
Selection
Show Original Data Ctrl+O
Send To Toolmanager Ctrl+T
Complementary Drill Through

**Figure 13-23** Evidence Visualizer’s Selection Menu

There are three menu items:

- *Show Original Data* causes the records corresponding to the selected item to be displayed in a record viewer.
- *Send to Tool Manager* causes a filter operation to be inserted at the beginning of the Tool Manager history. The actual expression used to do the drill-through is determined by
  - – the values selected in the Main Window, and
  - – the class(optionally) selected on the right.

  All selected values within a single attribute are ORed together. These terms for each attribute are then ANDed along with the class selection, if present, to form a drill-through expression that is used to do the filtering in Tool Manager. If nothing is currently selected, a warning message appears.

  For Figure 13-24 the filter expression would be:
  ```
  (`gross income`>60000.0) &&
  ((`occupation`==”Protective-serv”)||(`occupation`==”Tech-support”))
  &&(`education`==”Masters”)
  &&(`sex`==”Female”)
  ```
- *Complementary Drill Through* uses the complement of the expression defined by the selected objects for drill-through.

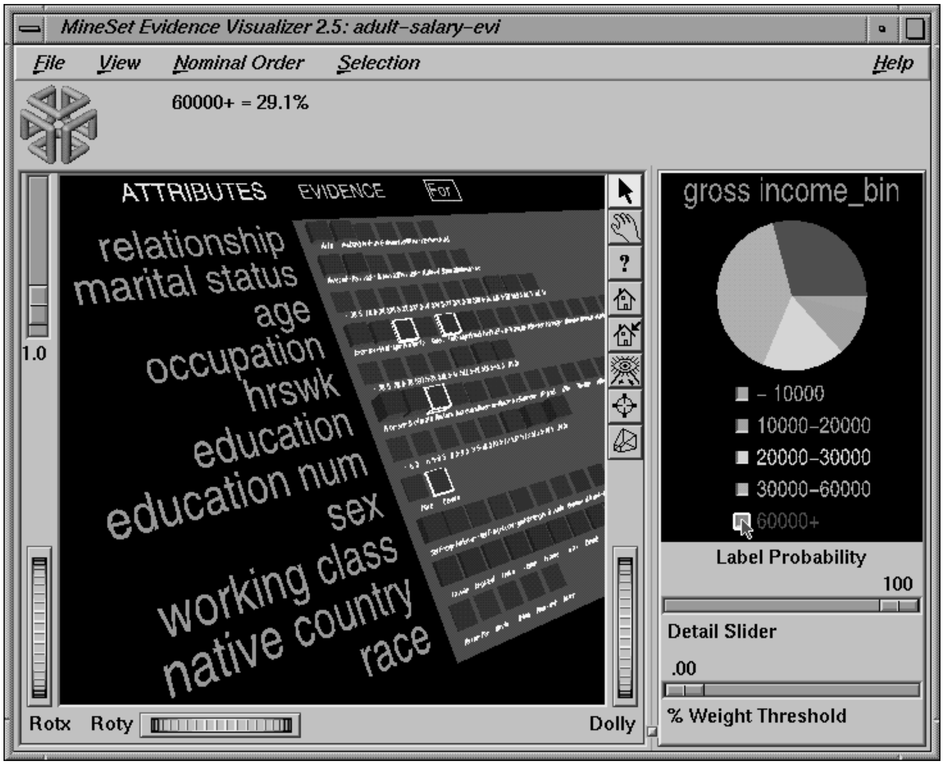


**Figure 13-24** Filtered Adult Dataset With Multiple Selection

## Sample Files

The following examples show cases in which classifiers might be useful. Each of these examples is associated with a sample dataset provided with MineSet. By running the inducer, you can generate the *.eviviz* files described below.

**Note:** The data files, which have a *.schema* extension, are located in */usr/lib/MineSet/data* on the client workstation. The classifier visualization files, which have a *.eviviz* extension, reside on the client workstation in */usr/lib/MineSet/eviviz/examples*.

### Churn

*Churn* is when a customer leaves one company for another. This example shows what causes customer churn for a telephone company. The data used to generate this example is in */usr/lib/MineSet/data/churn.schema*. The file */usr/lib/MineSet/eviviz/examples/churn.eviviz* shows the structure of the classifier induced using the attribute churned as the label. The error rate for this classifier is 12%. 14.1% of the records represent customers who churned. The two most important attributes, total_day_minutes and total_day_charge, are clearly correlated. A more accurate classifier can be induced if one of these attributes is removed first (the error rate becomes 11%). If you run the inducer after selecting Automatic Feature Selection from the Further Inducer Options, the error-rate drops to 10.5% using only 4 attributes (total day charge, number of service calls, voice mail plan, and number of voice mail messages). All 29 customers who had a total_day_charge above 53.78 churned.

A high number of customer service calls is a predictor of churn. Many customer service calls might indicate frustration in using a complicated equipment or receiving unreliable service. Customers with the International plan are also more likely to churn. The people in some states were much more likely to churn than those in others; for example, California and New Jersey have the most churn, Virginia the least. To see just those states that have more than 2% of the total number of records, slide the % Weights Threshold slider all the way to the right. This eliminates most of the values for state from the display. If you also select Nominal Order > Weight, then the state with the most records, West Virginia (WV), is left-most. Many of the attributes (at the bottom of the list) are not useful in discriminating churn. Note that day_charge is a great predictor, but night_charge is not.

### Origin of Cars

The *cars* dataset contains information about different models of cars from the 1970s and early 1980s. Attributes include *weight*, *acceleration*, and miles per gallon (*mpg*). The file */usr/lib/MineSet/eviviz/examples/cars.eviviz* shows the structure of the Evidence Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/cars.schema* with the label set to origin (Japan, U.S., Europe) and the cylinders column changed to type string. The cylinders were changed to type string in order to see all values and avoid the automatic discretization.

If you have a dataset of car attributes, you might want to know what characterizes cars of different origins. From the distribution of label values in the pie on the right we can see that most cars in this dataset were made in the U.S. (62.5%) and a smaller number in Japan (20.2%) and Europe (17.3%). Clearly brand is the best predictor of origin, since each brand is associated with only one country of origin. For this reason, it has the highest importance and is at the top of the list. By looking at the height of the pies, it can be seen that many cars have four cylinders, most weigh less that 3000 lbs and most can reach 60 miles per hour in less than 20 seconds but more than 13.

Look at the distribution of slices for individual attribute values. If a car has an engine size >169 cubic inches, it is almost certainly made in the U.S.; it certainly was not made in Japan. Other pies show that U.S. cars generally have six or eight cylinders, low miles per gallon, high horsepower (over 134), heavy weight (over 2981 lbs), and fast acceleration. Japanese cars have better gas mileage, three or four cylinders (and a few six cylinders), and smaller engines. If you click “Europe” in the Label Probability Pane, you can see bars representing evidence for a car being European. For example, five cylinders strongly indicates that a car is European. The height of the corresponding pie, however, shows that there were only three cars with five cylinders in the data. If a car’s mileage is good, there is much evidence for it being European. If a car’s mileage is > 41, then there is an 83% chance that it’s European. If a car is European, there is only a 10.4% chance that its mileage is better than 41 mpg. But only 2% of Japanese cars—and no U.S. cars—have mpg in this range, so Europe gets the most evidence.

Suppose you wanted to predict where a car came from knowing only that it got 40 mpg and weighed 3000 lbs. Select the appropriate pies (or bars): mpg=30.95-41.15 and weightlbs=2981.5+. The resulting probability distribution on the right shows 84% U.S., 16% European. There is no possibility it is Japanese because there were no Japanese cars in the training set with weightlbs>2981.5. If you run the inducer again with Laplace correction turned on (with a value of .5), you get a different answer: 16% chance for European, 82% chance for U.S., and a 2% chance for Japanese. This is because Laplace correction prevents any slice in the pies from going completely to 0. Certainly, there is no fundamental reason why the Japanese could not make a car that weighs more than 2981lbs; hence, when the probabilities (pies) are multiplied together, the possibility of predicting a Japanese car is not eliminated.

### Gender Attribution

The *adult* dataset contains information about working adults. This dataset was extracted from the U.S. Census Bureau. It contains data about people older than 16, with a gross income of more than $100 per year who work at least one hour a week. You might want to know how to characterize males and females. The file */usr/lib/MineSet/eviviz/examples/adult-sex.eviviz* shows the structure of the Evidence Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/adult.schema*, with the label set to sex, after removing the relationship column (which would have made the classifier trivial).

In the Evidence Visualizer, the Label Probability Pane shows that the prior probability of working males is higher than that of females.

- Marital status is the most important predictor of gender. If a worker is a married-civilian-spouse there is a greater probability of being male. A worker who is widowed and working, however, is much more likely to be female.
- The second attribute listed shows occupation. Study this to learn which occupations are popular with a particular gender. The various occupations are listed from left to right in order of decreasing male dominance: Armed forces (100%), Craft-repair (95%), Transport-moving (95%), and Farming-fishing (94%). Female trades are Private-house-service (94%) and Adm-clerical (67%). By clicking on the button next to “Female” in the Label Probability Pane, and then moving the mouse over occupation = Adm-clerical, one can see that 23% of females have an Adm-clerical job. Conversely, given that one’s job is Adm-clerical, there is a 67% chance that the gender is Female.

  Suppose you wanted to find out the probability of being female given that a person is widowed and has occupation = Adm-clerical. This can be done by clicking on the values and reading 95% from the text at the top when you move the mouse over the box next to “Female” (in select mode).
- If the working class is either self-employed-incorporated or self-employed-not-incorporated, the probability that the person is a male is higher. Conversely, if the working class is state-gov, the conditional probability that the person is a female is higher, but the posterior probability (after taking into account the prior probability) is not higher (click it and look at the posterior probability on the right). The size of the female slice increased by selecting state-gov, but not so much that it would lead you to predict that a person was female, given only that they worked for the state.

  By rotating the view, you can see that most people work in private industry by looking at the height of the charts.

- By looking at the gross-income attribute, you can see that the higher the income range, the higher the probability of being male.
- Education generally does not indicate much about gender, except for doctorate degrees, where you are more likely to find males.
- Different occupations have different distributions for males and females.
- The race attribute shows that African-Americans have a higher percentage of females working than the percentage of other races in the conditional probability. Click the value to see that the posterior is about equal between males and females.
- Males in this dataset work more hours per week than do females.

### Salary Factors

If you have a dataset of working adults, you might want to find out what factors affect salary. First bin gross_income into five bins, with thresholds at 10,000, 20,000, 30,000, and 60,000. Each record then has an attribute with one of five values. You can run a MineSet classifier to help determine what factors influence salary. The file */usr/lib/MineSet/eviviz/examples/adult-salary.eviviz* shows the Evidence classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/adult.schema* with gross_income divided into five bins using user-specified thresholds.

The attributes in the Evidence Visualizer are ranked by importance; thus, relationship, marital status, age, occupation, education, hours per week, and sex are considered most important. Since the label is numeric, a continuous spectrum is used to assign colors to each class. Red is assigned to the highest bin (60,000+). The class labels are listed in the Label Probability Pane according to slice size. As you click on values in the Main Window, the order of the class labels changes to keep the label for the largest predicted class at the top.

- *Relationship* shows that husbands and wives are likely to make more money than unmarried workers or workers not in a family. Wives have slightly higher incomes than husbands.
- *Marital status* shows that most people are married (the second chart from the left is tall). Married workers earn more money than unmarried people.
- *Age* shows that age is a crucial factor. Until the age of 61, when many people retire, the probability of making over $50,000 increases as workers get older.

- Different occupations yield different probabilities. Executive and professional jobs raise the evidence for making over $60,000 per year.
- *Education* is an important factor. When considering just education, the highest evidence for earning over $60,000 is given to workers whose educational level includes a masters or doctoral degree, or matriculation from professional schools.
- Hours per week show that the more hours worked, the higher the evidence for earning more money.
- *Sex* shows that being a female gives evidence for making less than $60,000 per year.
- Adjust the *Percent Weights* slider to remove values of native_country, education and occupation with low weights are removed.

### Iris Classification

In this dataset, each record describes four characteristics of iris flowers: petal width, petal length, sepal width, and sepal length. Each iris was further classified into the types iris-setosa, iris-versicolor, or iris-virginica. The goal is to understand what characterizes each iris type.

Before running a classifier, click the Column Importance tab in the Tool Manager's Classifiers tab; then click *Go!* You obtain a ranking of the importance of the features: petal width, petal length, and sepal length. You can map these to the axes in the Scatter Visualizer, with the iris_type mapped to the color and see the clusters.

The file */usr/lib/MineSet/eviviz/examples/iris.eviviz* shows the structure of the Evidence Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/iris.schema*.

In the Evidence Visualizer, we can see that petal length and petal width are excellent discriminatory attributes, while sepal length and sepal width are not as good. Move the importance threshold slider to the right to see that the sepal-based attributes disappear first.

### Mushroom Classification

The file */usr/lib/MineSet/eviviz/examples/mushroom.eviviz* shows the structure of the Evidence Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/mushroom.schema*.

The goal is to understand which mushrooms are edible and which ones are poisonous, given this dataset. There are over 8000 records in this set; thus, running this inducer might take several minutes. Note that under the default mode of the one-third holdout for accuracy estimation, a third of the records are kept for testing.

Each mushroom has many characteristics, including cap color, bruises, and odor. The Evidence Visualizer orders attributes by importance (that is, usefulness in predicting the label). Odor and spore print color appear at the top of the list because the distributions in the pies is most different from value to value for these attributes. Since all the attributes in this dataset are nominal, all the values are sorted from left to right by how well they predict edibility. You might want to order the values alphabetically or by weight (prevalence). To do this, select the appropriate method from the nominal order menu. You can see a characterization of poisonous mushrooms by changing the pointer to an arrow (click the arrow icon at the top right of the main screen), then clicking the button by that class label in the right pane. High bars are associated with values that indicate the mushrooms are poisonous.

In the Evidence Visualizer, move the Detail slider to the right. The attributes with the lowest importance are removed from the scene. The most important attribute by far is odor, as its importance is 92; all other attributes have importance less than 48. Almost all values are good discriminators, but if there is no odor (none), then there is a mix of both classes. The Evidence Visualizer lets you see specific values that might be critical, even if the attribute itself is not always important. For example, stalk_color_below_ring is not a good discriminatory attribute because most of the time it takes on the value white. White offers no predictive power because there are equal amounts of edible and poisonous mushrooms with this value. When stalk_color_below_ring takes the value gray or buff, it provides excellent discrimination, but there are very few mushrooms with these values.

### Party Affiliation

This dataset consists of voting records. The goal is to identify the party a congressperson belongs to given data about key votes. The dataset includes votes for each member of the U.S. House of Representatives on the 16 key votes identified by the *Congressional Quarterly Almanac* (*CQA*). The CQA lists nine types of votes: voted for, paired for, and announced for (these three are simplified to yes), voted against, paired against, and announced against (these three are simplified to no), voted present, voted present to avoid conflict of interest, and did not vote or otherwise make a position known (these three are simplified to an unknown disposition).

Before running a classifier, look at the 16 votes to see if you can perceive which features are important. Then run the Evidence Visualizer. For this dataset, you might want to order the values alphabetically, so that all no votes are on the left, undecided is in the middle, and yes is on the right.

Some issues clearly define one's party affiliation. Democrats tended to vote for a physician fee freeze and aid for El Salvador, while Republicans voted for adoption of a budget resolution and aid to the Contras in Nicaragua.

Immigration was an issue not split along party lines; nevertheless, politicians had strong positions on it because only 7 out of the 235 were undecided on this issue.

The file */usr/lib/MineSet/eviviz/examples/vote.eviviz* shows the structure of the Evidence Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/vote.schema*.

### Breast Cancer Diagnosis

The breast cancer dataset contains information about females undergoing breast cancer diagnosis. Each record represents a patient with attributes such as cell size, clump thickness, and marginal adhesion. The final attribute is whether the diagnosis is malignant or benign. The file */usr/lib/MineSet/eviviz/examples/breast.eviviz* shows the structure of the Evidence Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/breast.schema*.

In the Evidence Visualizer, you can see that sample_code_number was discretized into one range that is equally split, meaning that it does not indicate whether the breast cancer is benign or malignant.

### Hypothyroid Diagnosis

The hypothyroidism dataset is similar to the one for breast cancer. The file */usr/lib/MineSet/eviviz/examples/hypothyroid.eviviz* shows the structure of the Evidence Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/hypothyroid.schema*.

There are 3163 records in this dataset and most of them do not have hypothyroidism (95.45%). While this means that one can predict “negative” and be correct with high probability, it’s those people that have hypothyroidism that we are most worried about. In technical terms, the false negatives are very important.

Look at the pie for “tsh” between 6.35 and 27.5. It shows much evidence for hypothyroidism. When you click on it, however, the posterior pie still predicts “negative” because the prior probability for “negative” was so great.

This is a case where you might want to adjust the Loss Matrix to skew the posterior probability toward predicting hypothyroidism in order to avoid false negatives. There might be a high cost associated with predicting that someone is healthy when they actually have the disease; predicting them sick when they are actually healthy means they take a more accurate test or a treatment they do not need.

In the Evidence Visualizer, you can see that “fti” is very important. The first two ranges (besides the unknown) give a lot of evidence for hypothyroidism.

### Pima Diabetes Diagnosis

This dataset is a diagnosis problem for diabetes using statistics gathered from an Indian tribe in Phoenix Arizona. The task is to determine whether a patient has diabetes, given some medical attributes, such as blood pressure, body mass, glucose level, and age.

The file */usr/lib/MineSet/eviviz/examples/pima.eviviz* shows the structure of the Evidence Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/pima.schema*.

In the Evidence Visualizer, you can see that many attributes are irrelevant by themselves. As plasma_glucose increases, the probability of having diabetes increases. The number of pregnancies is also a good indicator when it is high (above 6), as is age (above 27).

### DNA Boundaries

The file */usr/lib/MineSet/eviviz/examples/dna.eviviz* shows the structure of the Evidence Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/dna.schema*.

There are 3,186 records in this DNA dataset. The domain is drawn from the field of molecular biology. Splice junctions are points on a DNA sequence at which “superfluous” DNA is removed during protein creation. The task is to recognize exon/intron boundaries, referred to as EI sites; intron/exon boundaries, referred to as IE sites; or neither. The IE borders are referred to as “acceptors” and the EI borders are “donors.” The records were originally taken from GenBank 64.1 (*genbank.bio.net*). The attributes provide a window of 60 nucleotides. The classification is the middle point of the window, thus providing 30 nucleotides at each side of the junction.

From the Evidence Visualizer, you can see that attributes near the center are chosen as very important. Attributes further away from the splice junction are less important.

If you click and select the charts in the left pane corresponding to “left_01: G” and “left_02: A”, then the pie chart in the label probability pane on the right will change to show the probability distribution of each class as predicted by the evidence classifier. Given these two values, the pie chart shows that the evidence model built assigns the highest probability to “intron/exon”, followed by “exon/intron” and “none”.

The accuracy improves slightly if you invoke automatic feature selection, although running time increases dramatically (sometimes hours). In such cases, run feature selection once, and continue mining only with the chosen features.

*Chapter 14*

# Inducing and Visualizing the Decision Table

This chapter discusses the features and capabilities of the Decision Table Visualizer, provides an overview of this tool, and discusses the methods of inducing Decision Tables. It then explains the Decision Table Visualizer's functionality when working with the

- Label Probability Pane
- Main Window

Finally, it lists and describes the sample files provided for this tool.

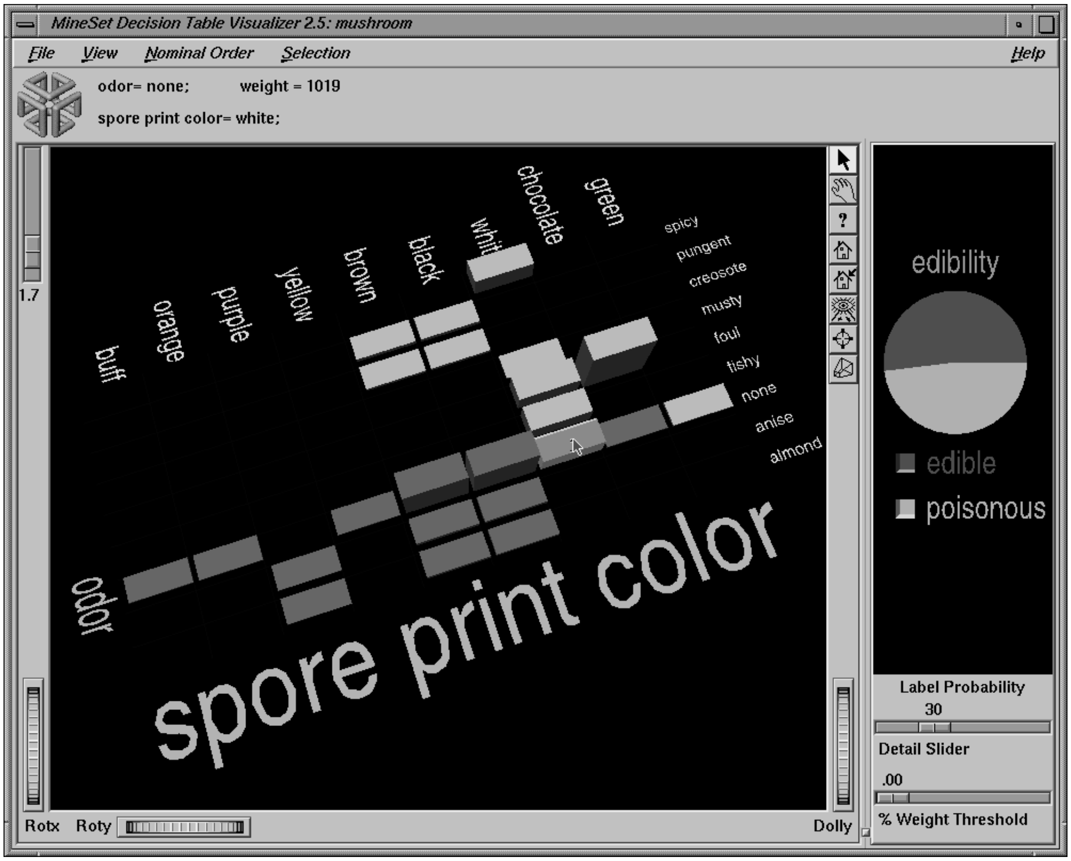
**Note:** It is assumed that you have read Chapter 10, "MineSet Inducers and Classifiers," before proceeding with this chapter.

## Overview

The Decision Table presents correlations between pairs of attributes, and can be used as a visualizer alone, or as a classifier and visualizer, in the same manner as MineSet's other inducers and visualizers. The underlying structure used for classification is a Decision Tree which splits on a single attribute at each level of the tree hierarchy. Such a structure is called an Oblivious Decision Tree. That attribute is rendered discrete in an identical manner across the whole level. Accuracy is inhibited to a small degree by representing the Decision Tree in this way, but the advantage is a uniform structure in a compact tabular form, which can easily show correlations between pairs of attributes at adjacent levels in the tree.

The method of classification used by Decision Tables is similar to that of a Decision Tree. Classification is done by picking the majority class of the region in which the example is found. If a record to be classified falls in a region where no training data occurred, classification is done by picking the predominant class one level up in the table hierarchy.

An example Decision Table is shown in Figure 14-1 for the mushroom dataset. It is hierarchical in structure like a Decision Tree, but breaks the data down by two attributes at each level instead of one. Decision Tables do not assume that the attributes are independent.



MineSet Decision Table Visualizer 2.5: mushroom

odor= none; weight = 1019

spore print color= white;

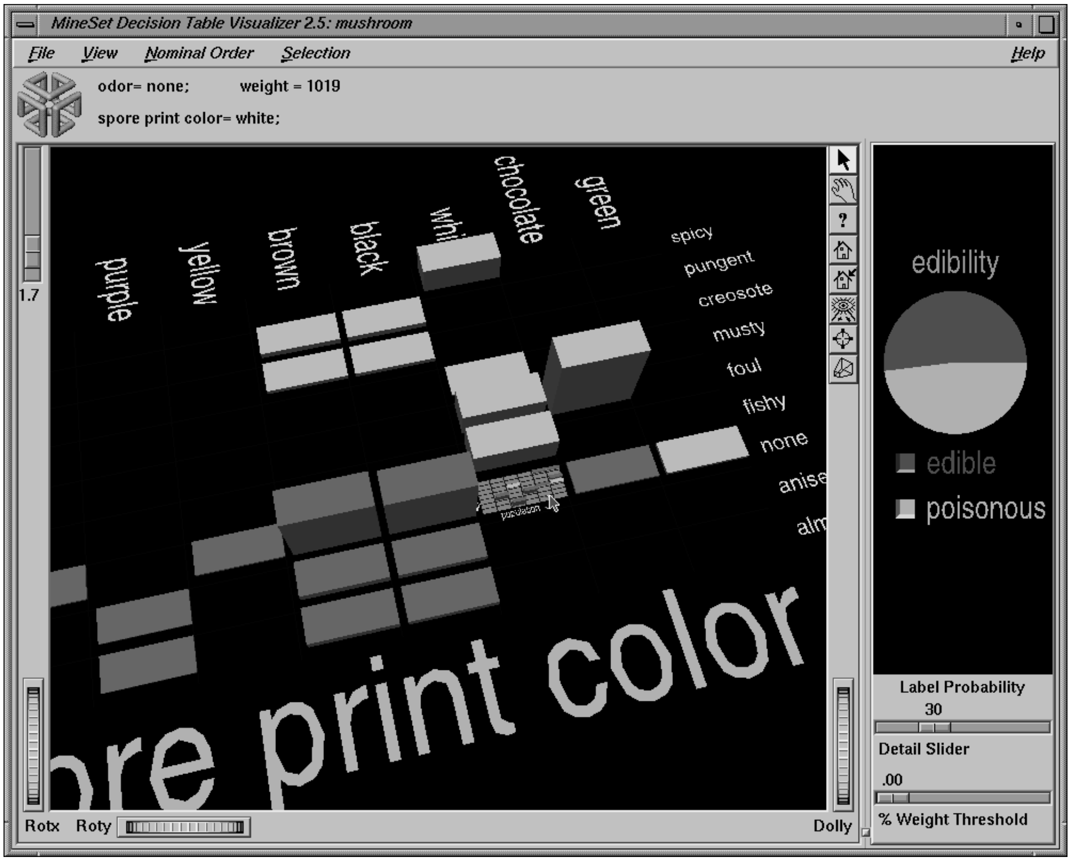
Label Probability 30

Detail Slider .00

% Weight Threshold

**Figure 14-1** Decision Table for the Mushroom Dataset

You might, for example create a Decision Table from the mushroom dataset to determine mushroom edibility (see Figure 14-1). The Main Window (on left) shows the top level of detail for a Decision Table induced from the mushroom dataset. Odor and spore-print-color were chosen to be at the top level because doing so improves the accuracy of the underlying classifier. In this dataset a dependence is shown between odor and spore-print-color at the top level. There is only one top level block with any ambiguity, meaning more than one class is present. It is the block with odor=none and spore-print-color=white. When you drill down to the next level (by clicking the right mouse button over the chart) the attributes habitat and population are shown at the next lower level (see Figure 14-2). The result of zooming in close to this drilled-down region is shown in Figure 14-3.



MineSet Decision Table Visualizer 2.5: mushroom

odor= none; weight = 1019

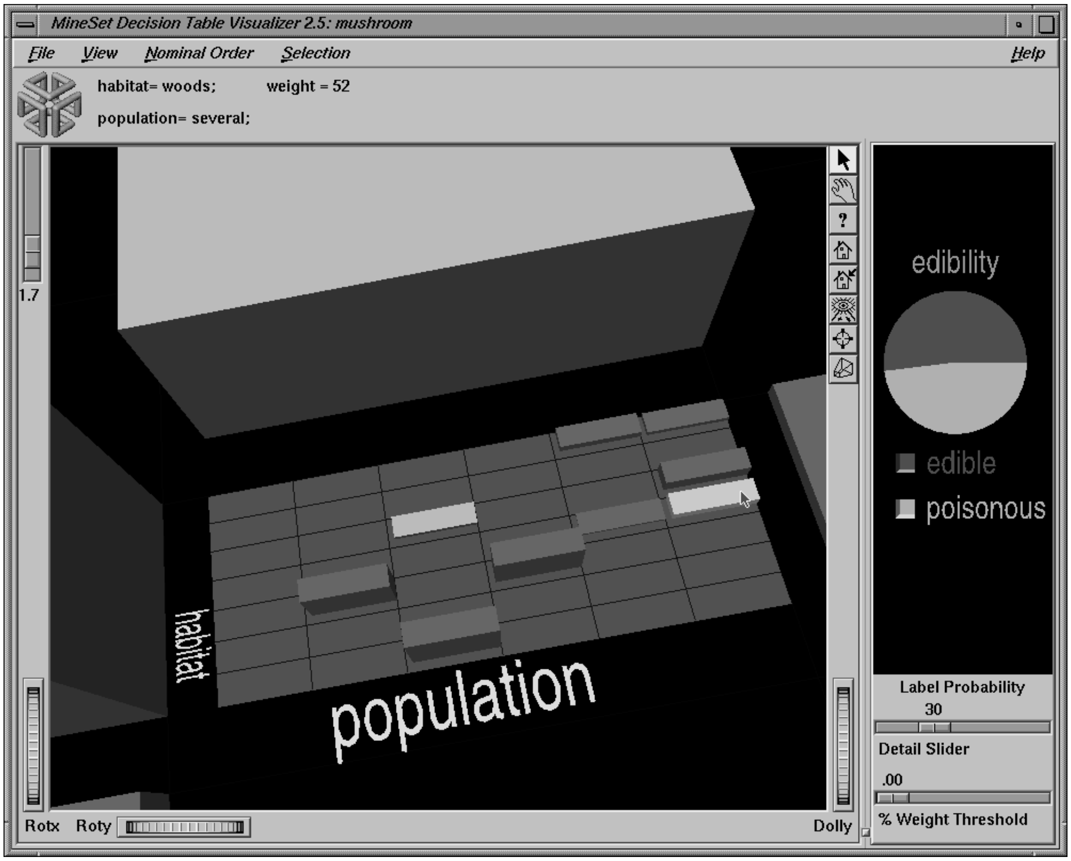
spore print color= white;

Label Probability 30

Detail Slider .00

% Weight Threshold

**Figure 14-2** Decision Table for the Mushroom Dataset, Showing Drill-Down



MineSet Decision Table Visualizer 2.5: mushroom

habitat= woods; weight = 52

population= several;

Label Probability 30

Detail Slider .00

% Weight Threshold

**Figure 14-3** Mushroom Dataset Close-Up of “odor=none and spore-print-color=white”

The Decision Table Visualizer may be used to answer questions such as:

- When you know the values for only a few attributes, what can you predict for a new record? If the attributes for which you know the values appear in the top levels of the hierarchy, then this question is answered precisely, instead of approximately, as with the Evidence Visualizer.
- How are the records distributed with respect to the label for the combination of attribute values that you are interested in?

The *prior probability* for each class label is depicted in the pie chart in the Label Probability Pane, on the right of the screen. The prior probability for a class label is the probability of seeing this label in the data for a randomly chosen record, ignoring all attribute values. Mathematically, this is the number of records with the class label divided by the total number of records.

The *probability distribution* for each rectangular block or cake in the Main Window on the left, shows the proportion of records in each class considering only records having that particular combination of values. These probabilities are precise for the data given.

By default, values of nominal attributes are sorted by how well they predict one of the classes. This helps identify important values. If the label is a binned attribute, the class that is the highest bin is used. If the label is nominal, then the class with the largest slice in the prior probability pie is used. When you select a particular class, and request a sort by label probability (*nominal ordering > sort by label probability*), that class determines the order of the result. Alternatively, the values of the nominal attributes can be sorted alphabetically or by weight. Values of binned attributes are always shown in their natural order.

When you drill down into a rectangular cake (using the right mouse button) the data represented by that cake is redisplayed in a new matrix of cakes where the attributes assigned to that level of detail are used as the axes. The cake charts sit on top of a gray base. If the base is completely covered with cakes, then every combination of values at this level is represented by the data. Often much of the base is uncovered. This shows regions where no data exists. In a very sparse dataset there are large regions that are empty. Picking or selecting a gray base has the same effect as selecting the cake that was one level up in level of detail. Drilling down on a base causes every cake sitting on top of it to expand to the next level of detail.

If an attribute has unknown (NULL) values, then the unknown values are denoted by a question mark (?). The NULL always appears as the first value if present and does not get sorted with the rest. It is possible to toggle the display of NULL values using *View > Show Null Values*.

If a cake is selected (left mouse click) on the left, then the probability pie on the right will show a posterior probability distribution which exactly matches that shown by the cake. When more than one cake chart on the left is selected (Shift-left mouse click), then the pie on the right will show the probability distribution (with respect to the label) for the set of records defined by the selected cakes. It is also possible to select a whole group of cakes by selecting the gray base below them. This has the same effect as selecting the cake one level up in the hierarchy.

Classes are listed under the pie chart on the right, and are in order of slice size. The class with the largest probability is at the top. As values on the left are selected, this order changes to reflect the changing probability pie. The class that would be predicted given current selections is shown at the top. If the label is a binned attribute the order of the classes is not changed on slice size. In addition, if the label is a binned attribute, colors are assigned according to a continuous spectrum: the highest bin is red; otherwise, random colors are used.

## Inducing Decision Tables

A Decision Table classifier can be induced, or generated automatically, from data. The data is made up of records, and a label associated with each record. (See Chapter 10, "MineSet Inducers and Classifiers")

The automatic induction of Decision Table classifiers is a process in which record counts (or more generally record weights) are used to calculate the probabilities using the following method:

1. All continuous attributes are separated into discrete bins, so that class distributions in these ranges are as different as possible. The number of ranges is determined automatically. You can override automatic binning for any attribute by explicitly binning using Tool Manager.
2. The prior probabilities are the proportions of each class in the training set.

The number of cakes in any row along one of the axes (attribute) pairs shows the number of discrete ranges produced by the inducer. If there is just one range, it means that this attribute by itself was not useful in predicting the label. Initially, the prior probabilities of the labels are displayed in the Label Probability Pane.

There are three ways to assign attributes to X and Y axes at every level in the Decision Table hierarchy: manually, automatically, and automatically with feature search.

The classifier can have a loss matrix. When the classifier is applied, the loss matrix skews the predictions. In the visualization, the loss matrix can be used to adjust the posterior probability distribution.

## File Requirements

The Decision Table Inducer requires the following files:

- A data file (*.data*) consisting of rows of tab-separated fields.
- A *.dtableviz* file containing the schema.The format of this schema is the same as described in “The .schema File” in Appendix A.
- A training set, as described in “Training Set” in Chapter 10. Files are generated by extracting data from a source (such as a MineSet ASCII or binary file, or a table in an Oracle, INFORMIX, or Sybase database).

To apply the generated classifier, you should have a dataset of records with the attributes used by the classifier, except that the label need not be present.

## Running the Decision Table Inducer

There are two ways to run the Decision Table inducer:

- From the Tool Manager

  Connect to the server and select a data source (see “Choosing a Data Source” in Chapter 3).

  From the File menu, choose Open New Data File. Log in to a server, and enter the filename. For the example shown here, the filename entered is */usr/lib/MineSet/data/mushroom.schema*. In the Data Transformation panel you see 23 discrete attributes. Select the Mining Tools tab in the Data Destination panel and click the Classify tab. Select edibility as the discrete label. Select the Decision Table inducer, and ensure you have selected the *Classifier & Error* mode. To run the Inducer, click *Suggest* then click *Go!*.

  The status window shows the progress and statistics, and the Decision Table Visualizer is launched automatically. You can also interrupt the automatic attribute suggestion process by selecting *Cancel* or *Show Viz Now* in the progress dialog. Selecting *Show Viz Now* stops the current server computation and uses the intermediate result to construct the Decision Table for the columns mapped so far. Alternatively you may manually map columns to the X and Y requirements as described in the next section.

- From the command line

  To induce a Decision Table classifier from the command line, refer to step 6 in “Starting the Decision Table Visualizer” on page 438.

## Starting the Decision Table Visualizer

As with the other visualization tools, there are six ways to start the Decision Table Visualizer:

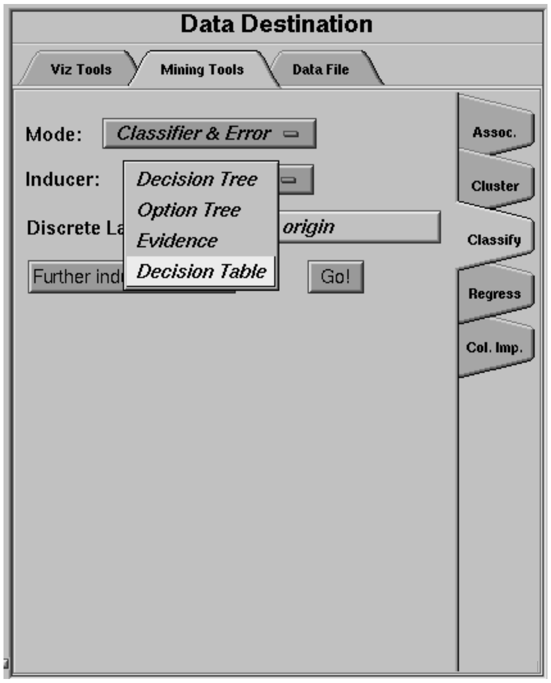
1. Run the Decision Table Inducer from the Tool Manager under the Classify tab. After the inducer builds the classifier, it automatically invokes the Decision Table Visualizer. See below for details about using the Tool Manager in conjunction with the Decision Table Visualizer.
2. Use the Tool Manager to start the Decision Table Visualizer from the Visual Tools menu. (See Chapter 3 for details of the Tool Manager's functions, which are common to all MineSet tools.)
3. Double-click the Decision Table Visualizer icon on your Silicon Graphics desktop. The startup screen requires you to select a data file by choosing File > Open.
4. If you know what configuration file you want to use, double-click the icon for that configuration file. This starts the Decision Table Visualizer and automatically loads the configuration file you specified. This works only if the configuration filename ends in *.dtableviz.* (Configuration files created for the Decision Table Visualizer with Tool Manager all carry the *.dtableviz* suffix.)
5. If you know what configuration file you want to use, drag its icon onto the Decision Table Visualizer icon. This starts the Decision Table Visualizer and automatically loads the configuration file you specified.
6. Start the Decision Table Visualizer from the UNIX shell command line by entering this command at the prompt:

   **`dtableviz`** [*dataFile*]

   Here, *dataFile* is optional and specifies the name of the configuration file to use. If you don't specify a configuration file, you then must use File> Open to specify one.

## Configuring the Decision Table Inducer Using the Tool Manager

To access the options for configuring the Decision Table inducer, select the Mining Tools tab on the Data Destination panel, shown in Figure 14-4.



Mode: Classifier & Error

Inducer:

Discrete La origin

**Figure 14-4** Data Destination Panel in Tool Manager Showing Classifiers

From the tabs at the right, select Classify. Ensure that the inducer you select is Decision Table. Your selections in the Mode and Inducer menus determine the options available in the Further Inducer Options menu. After you have made your selections in these menus, click *Go!* to run the inducer, which, in turn, creates the classifier. Or you can simply click *Suggest* and then *Go!*

## Discrete Labels

The Discrete Labels menu provides a list of available discrete labels selected from the dataset you chose. Discrete attributes (binned values, character string values, or a few integers) have a limited number of values. You should select a label attribute with few values—two or three (see "Training Set" in Chapter 10). If there are no discrete attributes, the menu shows *No Discrete Label*, and the *Go!* button is disabled. You then must create a discrete attribute by binning or adding a new column, using the Tool Manager's Data Transformations panel.

## Classifier Name

The generated classifier is named with the prefix of the session filename (as determined in Tool Manager) and the suffix *-dtable.class*. By default, all classifiers are stored on the server in the *file_cache* directory, which defaults to *mineset_files*. These classifiers can be used for future classification of unlabeled records; that is, they can be used to predict the labels for unlabeled datasets (see "Applying a Model" and "Backfitting in Error Estimation" in Chapter 10).

## Exploring Data by Mapping Columns to Axes

You can explore the relationships between attributes in data by mapping columns to X and Y axes. Select a column name in the Current Columns panel of the Data Transformations pane of Tool Manager window, then select an item in the X-axis or Y-axis windows. The first two columns mapped are shown at the top level, and subsequent mappings descend through the levels. If you map an odd number of attributes, the last level of detail shows a single column of cakes corresponding to the values of that odd attribute. If an interaction between two attributes is suspected, map one attribute to the X axis and the other to the Y axis. If you have no idea which attribute to map to which axis, simply click the *Suggest* and *Go* button.

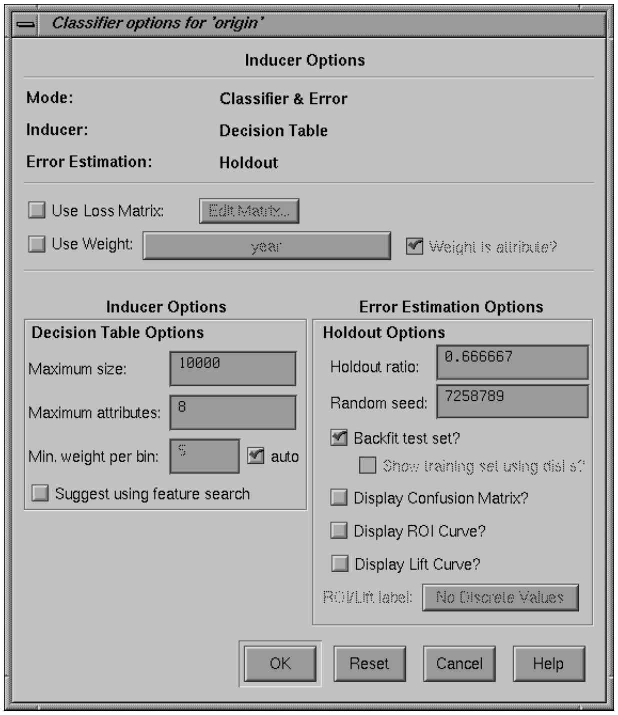
There are two different ways to Suggest: with or without feature subset search in the further inducer options turned on:

- *Checkbox Off* runs Column Importance to find the features. Column Importance is described further in Chapter 17, "Column Importance."
- *Checkbox On* begins with Column Importance, then runs through all possible orders, beginning with the order recommended by Column Importance. An error estimate is run at every stage, and each option is explored. Predictably, this can be a tedious process, and if you become impatient you can click *Stop* at any time. The longer the feature search continues, the more accurate the resulting classifier.

## Decision Table Options

Selecting Further Inducer Options causes the Inducer Options dialog box (Figure 14-5) to appear. This dialog box consists of four panels:

- The top panel indicates the choices you made in the Tool Manager's Data Destination panel.
- The second pane from the top lets you set the loss matrix and the weight attribute. See "Loss Matrices" and "Weight Setting" in Chapter 10.
- The bottom-left panel lets you specify further Inducer Options.
- The bottom-right panel lets you specify the Error Estimation Options (unless the mode you chose in the Data Destination panel was Classifier Only, in which case this area is empty). The options shown in this panel depend on the type of Error Estimation you chose (see "Applying Models, Testing Models, and Fitting New Data" in Chapter 10).



Classifier options for 'origin'

Inducer Options

Mode: Classifier & Error

Inducer: Decision Table

Error Estimation: Holdout

□ Use Loss Matrix:

□ Use Weight: year ☑ Weight is attribute?

Inducer Options

Decision Table Options

Maximum size: 10000

Maximum attributes: 8

Min. weight per bin: 5 ☑ auto

□ Suggest using feature search

Error Estimation Options

Holdout Options

Holdout ratio: 0.666667

Random seed: 7258789

☑ Backfit test set?

□ Show training set using dist s?

□ Display Confusion Matrix?

□ Display ROI Curve?

□ Display Lift Curve?

ROI/Lift label: No Discrete Values

**Figure 14-5** Further Inducer Options

### Decision Table Inducer Options

To fine-tune the Decision Table induction algorithm, you can change the following Decision Table inducer options (see Figure 14-5).

- *Maximum size*

  This is particularly useful when you have a large dataset. By default, there is a limit of 10000 nodes (these nodes correspond exactly to the cakes in the visualization). Limit the size by clicking the checkbox and typing a number for the limit. Limiting the number speeds up induction and limits the storage required. Although restricting the size decreases the run time, it might increase the error rate.

- *Maximum Attributes*

  This option determines how many different columns you allow to participate in the Decision Table when searching. Limiting the attributes simplifies the result and speeds its arrival. This limit affects only columns added by the *Suggest* mode. Columns added manually are not subject to the limit.

- *Minimum Weight per Bin*

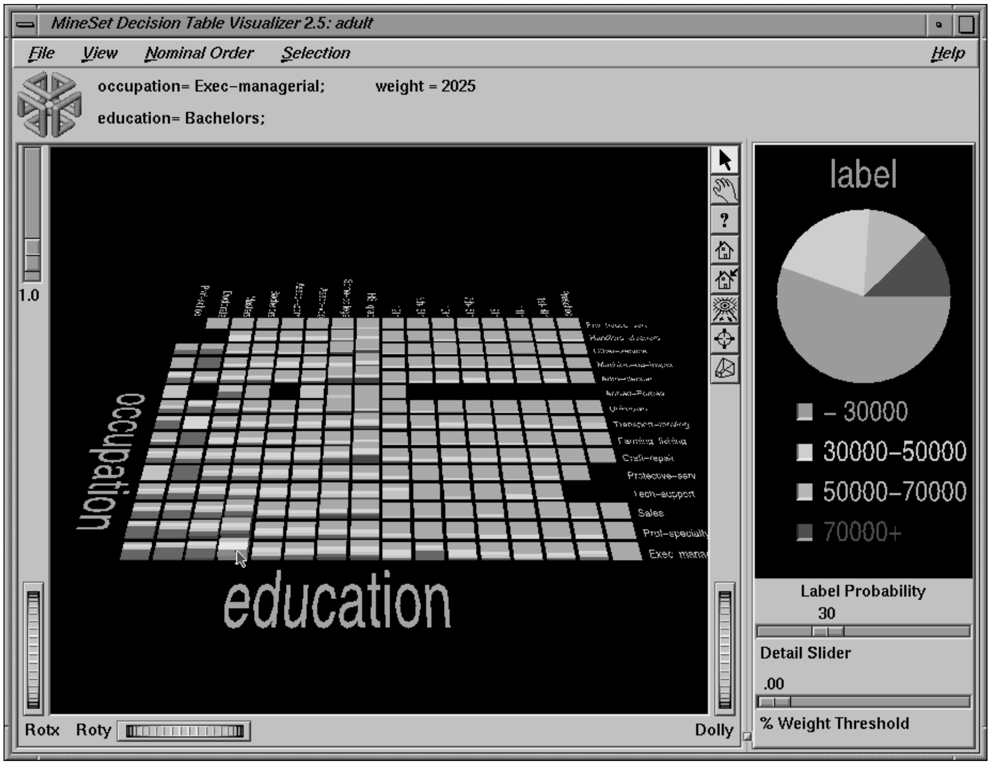
  The Decision Table inducer discretizes all continuous attributes. This option lets you define the minimum number of instances per bin. The automatic setting calculates this number based on the dataset size: the larger the dataset, the larger the bin size. If your dataset is very large, you might obtain more discrete ranges than you want. To reduce the number of bins, raise this value.

## Working in the Decision Table Visualizer's Main Window

If you started the Decision Table Visualizer without specifying a configuration file, the main screen shows the copyright notice for the Decision Table Visualizer. Only the File and Help pulldown menus are available. To view all menus and controls in the main window, open a configuration file. Use File > Open to see a list of configuration files.

When a valid configuration file is specified, the two panes in the main screen display graphics. For example, specifying */usr/lib/mineset/dtableviz/examples/adult.dtableviz* results in the output displayed in Figure 14-6.

In the Main Window pane on the left is shown the Decision Table. The elements in this Decision Table may be further subdivided into smaller and smaller cake charts (see Figure 14-6). Each chart shows the same information as a pie chart, but with rectangular slices, rather than wedges.



occupation= Exec-managerial; weight = 2025

education= Bachelors;

Label Probability 30

Detail Slider .00

% Weight Threshold

**Figure 14-6** Decision Table Showing Classifier Induced From adult94 Dataset

In the Label Probability Pane on the right, a list of all class labels appears under a large pie chart of the prior probability distribution. The color of the slices corresponds to the color associated with each class label; the size of the slices shows the proportion of data with each class label.

If you pick an object (place the cursor over it without clicking), you can see the values of the two attributes at that level of detail. The weight of records represented is proportional to the height of the cake. Picking a base (the gray block under the cake) shows the values for the two attributes for the cake one level higher in the hierarchy, together with the weight of records.

To see the values that define a particular chart, start by picking the base at the coarsest level of detail, and continue through the next most detailed base until you reach the base immediately below the chart of interest. The relevant value pair is then displayed at the top for each level of detail.

At each level of detail the attribute names are shown to the left and bottom of the array of charts; their values are shown to the right and top, respectively. If there is an odd total number of attributes, the lowest level shows only one attribute.

## Viewing Modes

Both of the Decision Table Visualizer’s window panes have two modes of viewing: grasp and select. Methods of viewing are the same as those for the Evidence Visualizer, see “Viewing Modes” in Chapter 13, and “Viewing Modes in the Main Window” in Chapter 13.

### Selecting Items in the Label Probability Pane

In select mode, the cursor appears as an arrow. You can then select one of the class labels by clicking the button to the left of it. Once a class label is selected, a white box appears around the button next to the label (see Figure 14-6). The size of that slice (the probability of predicting that label value) appears as text at the top of the display. To deselect a class label, click on it again. When you move the mouse over the button next to a class label in pick mode, the size of that slice (in percentage terms) appears in the top display.

If you select one of the classes in the Label Probability pane (on the right), and then select a cake chart on the left, you see probabilities and confidence intervals for that class shown in the top display, together with attribute values and weight. To select multiple charts on the left, hold down the Shift key while clicking the left mouse button.

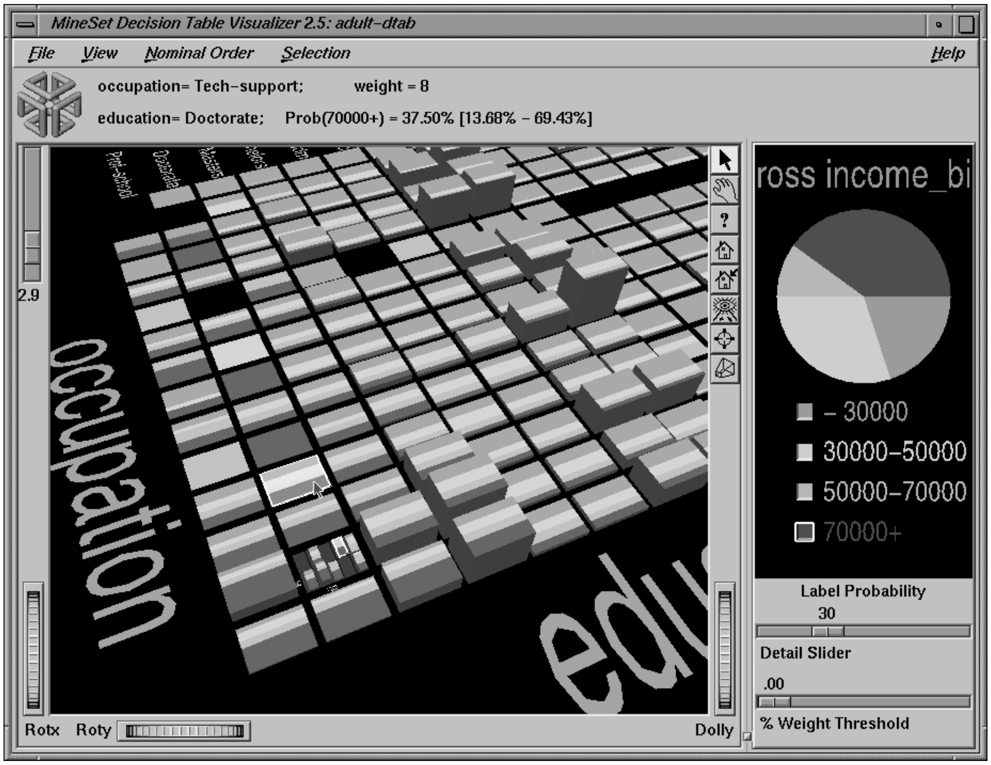
For example, choose the */usr/lib/MineSet/dtableviz/examples/adult.dtableviz* dataset. Select “class 70,000+” on right, then select a cake chart. The display at the top shows something like:

```
marital-status= Husband;           weight = 484
occupation= Exec-Manag;     Prob(70000+) = 15%[12%, 18%]
```

The numbers in brackets, `[12%, 18%]`, indicate a 95% confidence interval. That is, we are 95% confident that the actual percentage of likelihood that a husband executive manager earns over 70,000 is between 12% and 18%, assuming our dataset is a true random sample of the desired population.

### Selecting Items in the Main Window Pane

Select an object using the left mouse button. Select multiple objects using Shift-select, in the same way you do for other tools. For example, you can select a number of cakes at different levels of detail in the scene as shown in Figure 14-7. On the right the distribution for the classes shows just the records described by the multiple selections.



occupation= Tech-support;  weight = 8

education= Doctorate;  Prob(70000+) = 37.50% [13.68% - 69.43%]

**Figure 14-7** Example of Making Multiple Selections

### Drilling Down and Drilling Up

Drill down and drill up operate the same as in mapviz. (See"Drilling Down and Drilling up" in Chapter 6.) Drill down by clicking the right mouse button on one of the cakes. This replaces the one cake with smaller cakes which show the data broken down by the pair of attributes for the next level down. If the cursor is positioned on the background, clicking the right mouse drills down or up globally on all cakes. If the cursor is positioned on a gray base, clicking the right mouse button drills down on all cakes on that base. To drill up, click the middle mouse button when over a cake, a gray base, or the background.

## External Main Window Controls

The external controls for the visualizer associated with the Decision Table classifier are the same as those for the Map Visualizer. For a description of these controls, see “External Controls” in Chapter 5.

### Sliders

The Decision Table Visualizer contains three sliders: Height Scale, Detail Slider, and Percent Weight Threshold. The function of these sliders is the same as for the Evidence Visualizer. See “Sliders” in Chapter 13 for an explanation.

In using the Percent Weight Threshold Slider, the rectangular slices atop each cake show the distribution of the classes for the records represented by that cake. The height corresponds to the weight of the training set records that have reached this node (this is the number of records if weight was not set). In general, the higher the weight, the more reliable the class distribution the cake.

## Pulldown Menus

Four pulldown menus let you access additional Decision Table Visualizer functions: File, View, Selection, and Help. If you start the Decision Table Visualizer without specifying a configuration file, only the File and the Help menus are available.

### The File Menu

The File menu lets you open a new configuration file, save under a new name, print an image of the current display, start the Tool Manager, reopen the current configuration file, or exit the Decision Table Visualizer.

## The View Menu

The View menu lets you control certain aspects of what is shown in the Main Window (Figure 14-8).

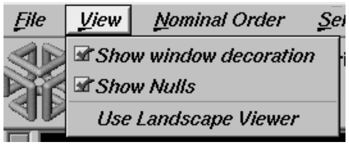


**Figure 14-8** Decision Table Visualizer's View Menu

This menu contains three options:

- *Show Window Decoration* lets you hide or show the external controls around the main window.
- Show Nulls toggles the display of null values. Null values, if present, are shown as the first value, offset slightly from other non-Null values.
- *Use Landscape Viewer* (or *Use Examiner Viewer*) switches to an alternative mode of 3D navigation. To understand navigation using the Landscape viewer see "Navigating With the Middle Mouse Button" in Chapter 5. Note that since the middle mouse button is used for navigation in the Landscape viewer, to drill-up you must click the middle mouse button while holding down the Ctrl key.

## The Nominal Order Menu

The Nominal Order menu lets you control how values for nominal attributes are ordered (Figure 14-9).

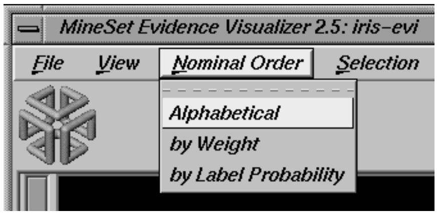


**Figure 14-9** Decision Table Visualizer's Nominal Order Menu

The three choices are:

- *Alphabetical* implies attributes with nominal values are sorted from left to right (or bottom to top) alphabetically.
- *Weight* sorts values from left to right, with those having the largest weight of records appearing toward the left.
- *Label Probability* (the default) sorts the values of nominal attributes by the size of the slices corresponding to one of the classes. If the label is a binned attribute, the highest bin is used by default. If the label is nominal, then whatever class has the largest slice in the prior probability pie is used by default. If a particular class is selected, and then sort by label probability is requested, the selected class is used for determining the ordering. In all cases, if there is a NULL value, it remains the first value.

## The Selection Menu

The Selection menu allows drill-through to the underlying data (Figure 14-10). To do a drill-through first select some combination of values and/or a class, then chose one of the two methods of drilling-through to the underlying records.

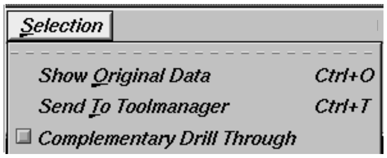

Selection
Show Original Data Ctrl+O
Send To Toolmanager Ctrl+T
□ Complementary Drill Through

**Figure 14-10** Decision Table Visualizer’s Selection Menu

There are three menu items:

- *Show Original Data* causes the records corresponding to the selected item to be displayed in a record viewer.
- *Send to Tool Manager* causes a filter operation to be inserted at the beginning of the Tool Manager history. The actual expression used to do the drill-through is determined by
  - – the cakes selected in the Main Window, and
  - – the class (optionally) selected on the right.

  Selected cakes are ORed together and then ANDed with the selected class, if present, to form a drill-through expression to do the filtering in Tool Manager. If nothing is selected, a warning message appears.

  For example, for figure 14-10, the filter expression corresponding to the selections is:

  ```
  (`gross income`>70000.0) &&
     ((`occupation`==”Tech-support”)&&(`education`==”Doctorate”)) ||
     (
       (`occupation`==”Prof-specialty”)&&(`education`==”Doctorate”)&&
       (`sex`==”Female”)&&(`race`==”Amer-Indian-Eskimo”)
     )
  ```

  The three major terms in this expression correspond to the selected class on the right, the selected cake at the top level, and the selected cake at the second level, respectively.
- *Complementary Drill Through* uses the complement of the expression defined by the selected objects for drill-through.

## The Help Menu

The Help menu provides access to six help functions. These are the same for all MineSet tools (see“The Help Menu” in Chapter 6.)

## Sample Files

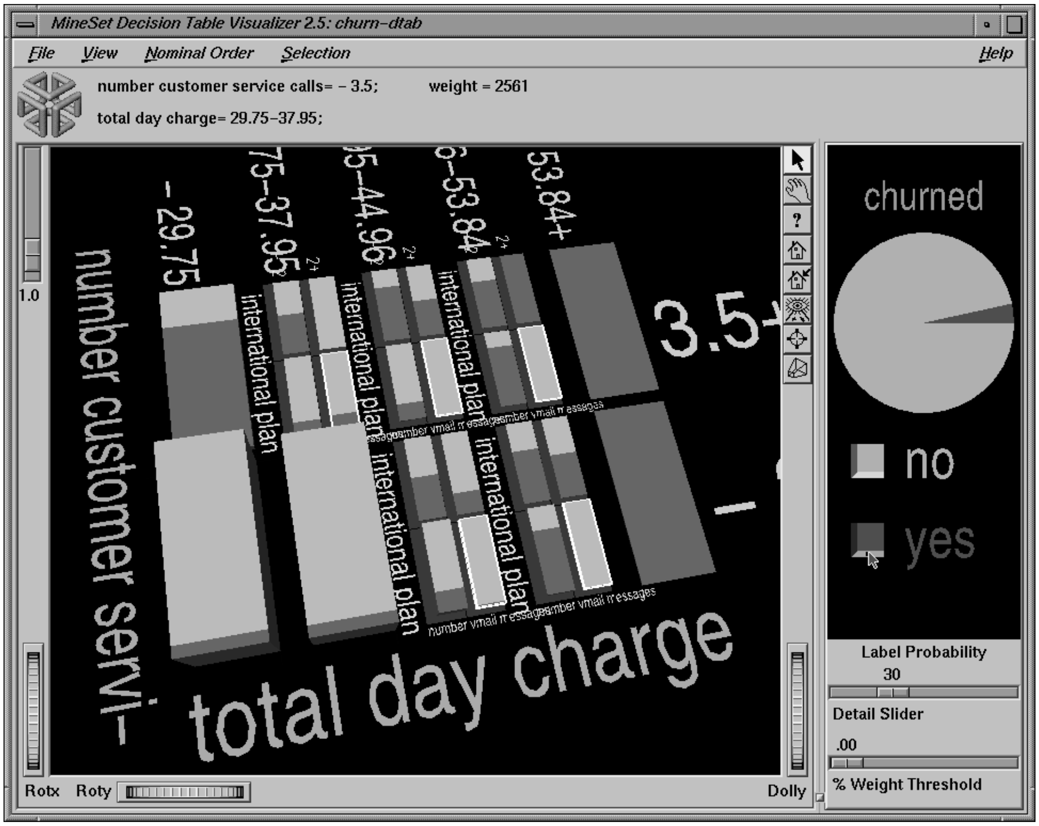
The following examples show cases in which the Decision Table can be useful. Each of these examples is associated with a sample data file provided with MineSet. By running the Decision Table inducer (with suggest using feature search turned on in the further inducer options), you can generate the *-dtab.dtableviz* and *-dtab.dtableviz.data* files described below.

**Note:** The data (*.data*) and accompanying schema (*.schema*) files are located in */usr/lib/MineSet/data* on the client workstation. The classifier visualization files, which have a *-dtab.dtableviz* extension, reside on the client workstation in */usr/lib/MineSet/dtableviz/examples*.

### Churn

*Churn* is when a customer leaves one company for another. This example shows what causes customer churn for a telephone company. The data used to generate this example is in */usr/lib/MineSet/data/churn.schema*.

The file */usr/lib/MineSet/dtableviz/examples/churn-dtab.dtableviz* shows the structure of the classifier induced using the attribute churned as the label. The error rate for this classifier is 5.5%. Of the records, 14.3% represent customers who churned. The two attributes selected for the first level of detail were number_of_customer_service_calls and total_day_charge. By looking at the distribution over these two attributes, you can see that churn increases as total day charge increases, except when the total day charge is < 29.75, then the churn is high if the number of service calls is > 3. About 3/4 of the records have total day charge less than 38 and 3 or fewer customer service calls.



number customer service calls= – 3.5; weight = 2561

total day charge= 29.75–37.95;

Label Probability 30

Detail Slider .00

% Weight Threshold

**Figure 14-11** Drilling Down on the Churn Dataset

Begin to drill down on regions where its not clear when a customer churns. Figure 14-11 shows drilling down on all cakes in which there was not a clear majority class. The next attributes considered are international_plan and number_of_vmail_messages. Among those with heavy day charge, it appears clear that having the international plan and having few vmail messages correlates well with customer churn. Selecting the lower right cake in each of the drill-down regions, and then brushing with the mouse across the box next to "churned=yes" in the probability pane on the right, shows that only 3.4 percent of the customers in the selected regions churned.

Now drill down further on the cake in the upper left of each previous drill-down region. Doing so shows a very similar distribution for each. The consistent pattern shows: high total_evening_charge and high total_international_charge correlate well with churn. You can even drill-down another level to see the effect of total_international_calls, but doing so leaves so few records from which to draw conclusions, you could not be confident of the distributions seen. If you are interested in how total_international_calls affects churn and how it correlates with other variables, return to the Tool Manager and explicitly map total_international_calls to a higher level in the hierarchy, and rerun the decision table.

Although “state” is fairly well correlated with churn, it was not selected because the algorithm has a built-in preference for variables with few values. This prevents the algorithm from selecting attributes like social security number which uniquely identify each record, thus yielding high training set accuracy, but are not useful for classifying future unlabeled data.

### Origin of Cars

The *cars* dataset contains information about different models of cars from the 1970s and early 1980s. Attributes include weight, acceleration, and miles per gallon (mpg). The file */usr/lib/MineSet/dtableviz/examples/cars-dtab.dtableviz* shows the structure of the Decision Table Classifier induced for this dataset. This file was generated by running the inducer on */usr/lib/MineSet/data/cars.schema* with the label set to “origin” (Japan, U.S., Europe).

Since the brand attribute uniquely determines the origin, the structure of the classifier is extremely simple. The only two attributes shown are brand and cylinders. It is interesting to see which brands tend toward high or low cylinder types. For example, there are 21 different models of Mazda, and 18 models of Honda, but they all have 5 or fewer cylinders. Conversely, Cadillac only makes cars with six or more cylinders.

This example could probably be made more interesting by first removing the brand attribute. Another useful transformation might be to convert cylinders to string so each unique cylinder value is shown, rather than a bin. Alternatively, one can create additional levels of detail beyond brand and cylinder, by mapping them explicitly.

### Gender Attribution

The *adult* dataset contains information about working adults. This dataset was extracted from the U.S. Census Bureau. It contains data about people older than 16, with a gross income of more than $100 per year who work at least one hour a week. You might want to know how to characterize males and females.

The file */usr/lib/MineSet/dtableviz/examples/adult-sex-dtab.dtableviz* shows the structure of the Decision Table Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/adult.schema*, with the label set to sex, after removing the relationship column (which would have made the classifier trivial). To make it easier to see the distribution of records for each combination of values, you can scale the cake heights using the scale slider on the left.

In the Decision Table Visualizer, the Label Probability Pane shows that the prior probability of working males is higher than that of females. The Evidence Visualizer showed us that marital_status and occupation are very important attributes for determining gender, however, it did not show us the dependencies between these two attributes. The top level shows several interactions. For example, most people with occupation craft repair are married civilian spouses (more specifically 98.6 of them are husbands), while most people with occupation “Other-service” have “Never-married” (48% male).

At first it may seem odd that most of the people with “marital_status = Married-civilian-spouse” are male, but once you consider that this data was probably gathered from tax returns, it seems reasonable that the wives of these males are not working but filing jointly with their husbands.

The divorce rate seems highest among those with ″occupation = Admin-clerical”. Those in “Other-service” also have high divorce rates, but they seem to prefer separation, as the number who are separated is even greater than that of “Admin-clerical”.

Suppose you wanted to find out the probability of being female given that a person is “widowed” and has “occupation=Adm-clerical”. In the evidence visualizer one can get an approximate answer (94.7% female) for this by clicking on these two attribute values. Here we can get the exact answer by clicking the left mouse on the cake at the intersection of these two values (95.2% female).

Drill down to the lowest level on the cake for “Married-civilian-spouse” and “Occupation= Unknown.” There is a pattern evident here more than any of the other combinations of occupation and marital status. For this cake, the younger members tend to be women, and the older members tend to be men.

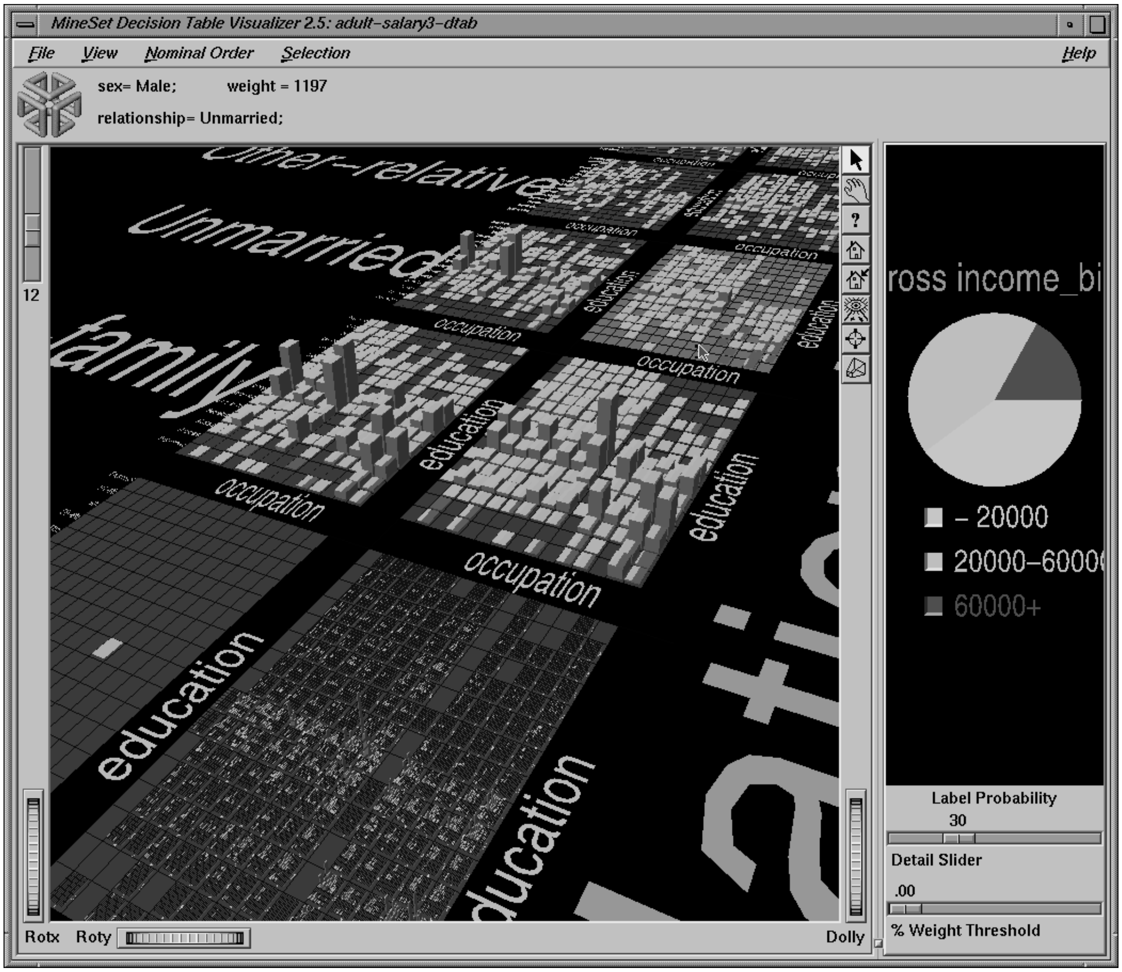
### Salary Factors

For a dataset of working adults, you might want to find out what factors affect salary. First bin gross_income into two bins, those that earn less that 50,000, and those earning over 50,000. You can run a MineSet classifier to help determine what factors influence salary. The file */usr/lib/MineSet/dtableviz/examples/adult-salary-dtab.dtableviz* shows the Decision Table classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/adult.schema* with *gross_income* divided into five bins using user-specified thresholds.

Since the label is numeric, a continuous spectrum is used to assign colors to each class. Also the classes in the probability pane on the right are not sorted by slice size because they have a numeric order. Red is assigned to the highest bin (50,000+).

The two attributes chosen at the top of the hierarchy are relationship and education_num. The attribute education_num is not particularly useful because it is simply an enumeration of the different educations possible, not years of education, as you might think. However there is an approximate correlation. Replace this column with education if you prefer to see the actual string values. If you simply remove the column, education_num, and rerun using feature search, the algorithm may not pick education at the top of the hierarchy because it has so many values.

The order of the attributes in this model were selected automatically to increase accuracy. Often a model in which domain knowledge is used to perform the mappings can give a more useful visualization. Such a model is provided in */usr/lib/MineSet/dtableviz/examples/adult-salary3-dtab.dtableviz*, and shown in Figure 14-12. Here the salary has first been binned into 3 ranges (20000, and 60000 are the thresholds). The attributes mapped at level one are: relationship and sex; level two has education and occupation; and level 3 has hrswk (hours worked per week) and age.



MineSet Decision Table Visualizer 2.5: adult-salary3-dtab

sex= Male; weight = 1197

relationship= Unmarried;

Label Probability 30

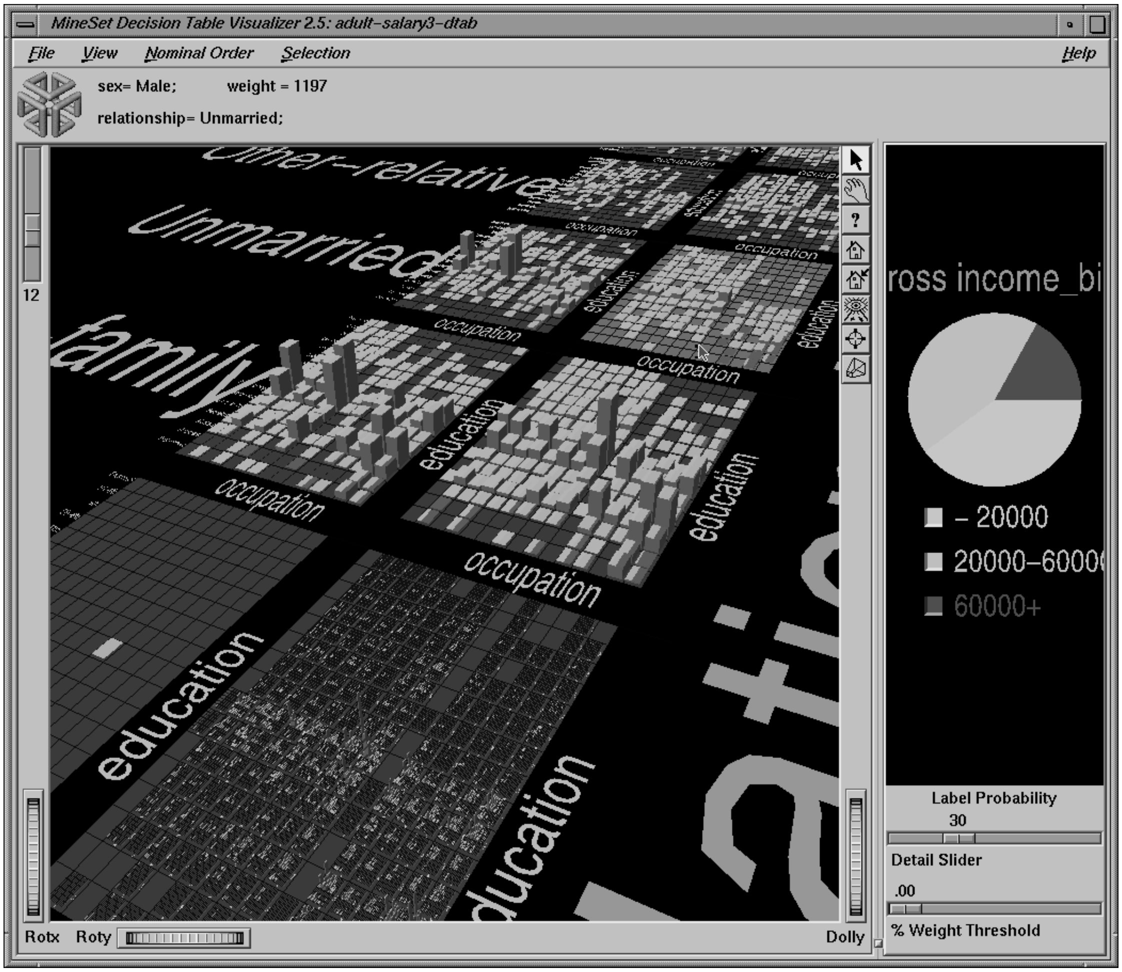
Detail Slider .00

% Weight Threshold

**Figure 14-12** Decision Table Visualizer Using the Adult Dataset

At the top level we know “relationship” and “sex” have a strong correlation. Of course we expect all husbands to be male, and wives to be female, but we can see right away this is not the case. By brushing on the cake for male wives we see that there are 3 of them and all their salaries fall in the 20,000-60,000 range. Drilling down on these cakes reveals more information about these anomalous records. You may wish to select these cakes (using the left mouse button) and drill through to the underlying data so you can find the values of all the other fields.

Click the right mouse on the background; this will drill down globally to the next level. Every cake is now replaced with a matrix for every combination of education and occupation. The ordering is the same for every matrix, and overall the ordering is by correlation with income. If you choose Nominal Order > by Weight from the pulldown menu the overall ordering will be by record weights. The most popular occupations and education levels will appear in the lower left corner of each matrix. High school grads is the most prevalent education level, and Professional-specialty is the most common occupation, but there are not many high school graduates whose occupation is professional specialty.



sex= Male; weight = 1197

relationship= Unmarried;

Label Probability 30

Detail Slider .00

% Weight Threshold

**Figure 14-13** Closer Inspection of the Adult Dataset

Returning to ordering of nominals by income, you can see distinct distributions for each combination of sex and relationship. There is not much difference between males and females whose relationship is not-in-family. The difference between unmarried males and females, however, is very pronounced. (See Figure 14-13). There is a very distinctive cluster of red cakes in the lower left of male matrix that does not exist in the female matrix. By scaling up the heights somewhat, you will notice that the female matrix has obvious spikes at occupation = “admin clerical” and “other service”. No such spikes are visible in the corresponding male matrix.

Click with the right mouse button on the most populous cake (male husbands). This operation may take a minute to perform because the visualizer needs to construct all the geometry for the next level for this cake. The geometry is constructed on demand because the time needed to create it all at the beginning would be excessive, and wasteful since the user rarely explorers most of the high detail regions. If you click on the background by mistake you may be forced to wait a very long time if the amount of detail at the next level is very long - as it is in this case. Figure 14-12 shows the result of drilling down on the male husband base.

Consider the many age by hrswk distributions that are displayed for every combination of occupation and education. The first surprising fact is that, in spite of the many hundreds of cakes shown, there is a single spike at that accounts for 2.5% of all husbands! (SeeFigure 14-13) If you had to pick characteristics for a typical husband, it would be reasonable to say he is a HS-grad doing craft-repair, aged between 41 and 59 and working between 38 and 41 hours a week.

Compare the salary distributions for husbands who are HS-grads in sales with those who are HS-grads and executive managers. Although the distribution of age and hours worked is similar, the probability of being in the income greater than 60,000 class is 34% for this group of managers, compared with 27% for the salesmen. To see these probabilities shown at the top, first click the button next to the 60000+ income class in the label probability pane on the right, then brush over cakes on the left.

### Iris Classification

In this dataset, each record describes four characteristics of iris flowers: petal width, petal length, sepal width, and sepal length. Each iris was further classified into the types iris-setosa, iris-versicolor, or iris-virginica. The goal is to understand what characterizes each iris type.

Before running a classifier, click the Column Importance tab in the Tool Manager's Classifiers tab; then click Suggest then *Go!*. You obtain a ranking of the importance of the features: petal_width, petal_length, and sepal_length. You can map these to the axes in the Scatter Visualizer, with the iris_type mapped to the color and see the clusters.

The file */usr/lib/MineSet/dtableviz/examples/iris-dtab.dtablerviz* shows the structure of the Decision Table Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/iris.schema*.

In the Decision Table Visualizer, we can see that petal_width is an excellent discriminatory attribute. When you add sepal_width you see that all instances of "iris_versicolor" appear in the sepal width<3.05 bin for those records which have petal width= 0.75-1.65.

Drill down on the three cakes which are not 100% pure. The top two cakes each contain a single instance of iris-versicolor which prevent them from being pure. For the sepal_width<3.05 cake it is very difficult to isolate the anomalous "iris-versicolor". For the sepal_width>3.05 cake, however, the iris_versicolor is isolated by using petal_length.

### Mushroom Classification

The file */usr/lib/MineSet/dtableviz/examples/mushroom-dtab.dtableviz* shows the structure of the Decision Table Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/mushroom.schema*.

The goal is to understand which mushrooms are edible and which ones are poisonous, given this dataset. There are over 8000 records in this set; thus, running this inducer might take several minutes. Note that under the default mode of the one-third holdout for accuracy estimation, a third of the records are kept for testing.

Each mushroom has many characteristics, including cap-color, bruises, and odor. In the Decision Table Visualizer odor and stalk-shape appear at the top level. Note that odor alone does an excellent job of discriminating edibility. Only when the “odor=none” and the stalk-shape is “enlarging” is there any ambiguity. So naturally we drill down on this lone cake. Now we see just the records with these 2 values broken down by their values for bruises and gill-size. Notice the interaction between gill-size and bruises. This interaction is nearly impossible to discern using any other classifier.

Since all the attributes in this dataset are nominal, all the values are sorted from by how well they predict edibility. You might want to order the values alphabetically or by weight (prevalence). To do this, select the appropriate method from the nominal order menu. If you considered either bruises or gill_size alone you would not be able to predict large classes of completely edible or poisonous mushrooms, but by considering them together, we see that if there are no bruises and the gill-size is broad, then all 814 mushrooms of this type are edible. Conversely, if there are bruises and the gill-size is narrow, then all 11 mushrooms of this type are poisonous. To disambiguate the other two cases we would have to drill down further.

There is actually a mapping which can completely discriminate among all the examples in our training set using only 2 levels. The attributes for these to levels are: odor, spore_print_color and habitat, population. The reason the automatic suggestion did not use this mapping was because of the preference for attributes with fewer numbers of values.

In the Decision Table Visualizer, move the % Weight Threshold slider to the right. Eventually the “odor=musty” will be deleted from the scene. The reason for this is that there are fewer than 1% of the records with odor=musty.

### Party Affiliation

This dataset consists of voting records. The goal is to identify the party a congressperson belongs to given data about key votes. The dataset includes votes for each member of the U.S. House of Representatives on the 16 key votes identified by the *Congressional Quarterly Almanac* (*CQA*). The CQA lists nine types of votes: voted for, paired for, and announced for (these three are simplified to yes), voted against, paired against, and announced against (these three are simplified to no), voted present, voted present to avoid conflict of interest, and did not vote or otherwise make a position known (these three are simplified to an unknown disposition).

Before running a classifier, look at the 16 votes to see if you can perceive which features are important. Then run the Decision Table Visualizer. For this dataset, you may wish to order the values alphabetically, so that all “yes” votes appear in the upper right and “no” votes appear in the lower left.

A the top level we see synfuels_corporation_cutback and physician_fee_freeze. There is a fascinating relationship between these variable that would be next to impossible point out with any other model. Everyone (but 3) who voted against physicians was a democrat. Nearly every democrat that voted against physicians also voted against the synfuels cutback (only 3 of 206 did not fit this pattern). Surprisingly, nearly every (all but 5) republican that voted for the physicians, voted against the synfuels cutback.This odd relationship between these very different issues hints that these bills may have been connected in ways that would require further investigation.

Most of the cakes at the top level are nearly pure except for the middle one (which contains only 6 records) and the one where the representatives voted yes on both issues. Here we can drill-down another level to discriminate the political affiliation of the representatives in this group. Doing so uses “anti-satellite test ban” and “adoption of the budget resolution” to further discriminate among the 55 representatives in this group.

The file */usr/lib/MineSet/dtableviz/examples/vote-dtab.dtableviz* shows the structure of the Decision Table Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/vote.schema*.

### Breast Cancer Diagnosis

The breast cancer dataset contains information about females undergoing breast cancer diagnosis. Each record represents a patient with attributes such as cell size, clump thickness, and marginal adhesion. The final attribute is whether the diagnosis is malignant or benign. The file */usr/lib/MineSet/dtableviz/examples/breast-dtab.dtableviz* shows the structure of the Decision Table Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/breast.schema*.

In the Decision Table Visualizer, mitosis and uniformity of cell shape are shown at the top of the hierarchy. If both attributes have low values at the same time the given sample is 99.2% likely to be benign. On the other hand, 100% of the training records that had high values for both, were malignant.

Drill-down on the four cakes that are not so pure. Now marginal adhesion and bare-nuclei are used to discriminate. There are far fewer records in each cake at this level; as a result there is more noise, and trends are more difficult to detect. High values for both marginal-adhesion and bare-nuclei seem to contribute to malignancy, but its uncertain. Note that the first value of bare-nuclei is null. The distributions for these null cakes are more suspect than others so you may wish to hide them by unchecking View > Show Nulls.

If you drill down globally two more levels, you can note a few interesting features. The cakes get very small, and there are large regions of the multi-dimensional space which are empty. There are a few tiny regions where many records are clustered. There is one huge spike (100% benign) where all the values are low This spike alone accounts for about 20% of the data.

### Hypothyroid Diagnosis

The hypothyroidism dataset is similar to the one for breast cancer. The file */usr/lib/MineSet/dtableviz/examples/hypothyroid-dtab.dtableviz* shows the structure of the Decision Table Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/hypothyroid.schema*.

There are 3,163 records in this dataset and most of them do not have hypothyroidism (95.45%). While this means that one can predict “negative” and be correct with high probability, it’s those people that have hypothyroidism that we are most worried about. In technical terms, the false negatives are very important.

This is a case where you might want to adjust the loss matrix to skew the posterior probability toward predicting hypothyroidism in order to avoid false negatives. There might be a high cost associated with predicting that someone is healthy when they actually have the disease; predicting them sick when they are actually healthy means they take a more accurate test or a treatment they do not need.

Using the Decision Table Visualizer on this dataset, we note:

- *If fti is null then tbg is not null and t3 is almost always null (drilling down-one more level).*
- Except for 2 instances, the only time *t4u* is null is when *fti* is null.
- *Hypothyroidism is more prevalent for lower values of for fti*

### Pima Diabetes Diagnosis

This dataset is a diagnosis problem for diabetes using statistics gathered from an Indian tribe in Phoenix Arizona. The task is to determine whether a patient has diabetes, given some medical attributes, such as blood pressure, body mass, glucose level, and age.

The file */usr/lib/MineSet/dtableviz/examples/pima-dtab.dtableviz* shows the structure of the Decision Table Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/pima.schema*.

Using the Decision Table Visualizer we note:

- *At the second level of detail you can see that few women under 28 have more than 6 pregnancies (only 4 do). You may wish to drill-through to these records to get all the information available for these 4.*
- High values of plasma glucose, body mass, indicate a greater likelihood of diabetes.

### DNA Boundaries

The file */usr/lib/MineSet/dtableviz/examples/dna-dtab.dtableviz* shows the structure of the Decision Table Classifier induced for this problem. This file was generated by running the inducer on */usr/lib/MineSet/data/dna.schema*.

There are 3,186 records in this DNA dataset. The domain is drawn from the field of molecular biology. Splice junctions are points on a DNA sequence at which “superfluous” DNA is removed during protein creation. The task is to recognize exon/intron boundaries, referred to as EI sites; intron/exon boundaries, referred to as IE sites; or neither. The IE borders are referred to as “acceptors” and the EI borders are “donors.” The records were originally taken from GenBank 64.1 (*genbank.bio.net*). The attributes provide a window of 60 nucleotides. The classification is the middle point of the window, thus providing 30 nucleotides at each side of the junction.

From the Decision Table Visualizer, you can see a surprising pattern not nearly as evident in any other classifier model. At the top level there is a pronounced interaction between left_01 and right_02. Exon/intron is only present if right_02 = T. Intron/extron is only present if left_01=G. For other values of left_01 and right_01 there are very few splice junctions.

Drill down globally to the next level (left_02 and right_01). Among the records where right_02 = T and left_01 = G we see a pattern which is consistent with the patterns along each edge.

*Chapter 15*

# Inducing and Visualizing the Regression Tree

This chapter discusses the features and capabilities of the Regression Tree Inducer. Its associated visualizer, the Tree Visualizer, is described in Chapter 5. This chapter provides an overview of this tool and discusses methods of using it to generate Regression Trees. It then explains the Tree Visualizer's functionality when working with regression trees. Finally, it lists and describes the sample files provided for this tool.

**Note:** It is assumed that you have read Chapter 10, "MineSet Inducers and Classifiers," before proceeding with this chapter.

## Overview

Regression is the task of predicting a continuous label value, given a set of descriptive attributes. A regressor is a predictive model that performs regression. Regression and classification are similar, the difference being that in classification the predicted label can take on only a small number of discrete values. For example, an iris may be classified by type as either iris-setosa, iris-versicolor, or iris-virginica. In regression, the predicted label can be any value in a continuous range, for example, an individual's annual income may be any amount greater than zero.

MineSet can build a regressor automatically from a training set using an algorithm called an inducer. The training set consists of records in the database for which the continuous label is known. For example, you could supply a database table with columns (such as age, education, occupation, hours worked per week, and so forth), and one column containing descriptive attributes (gross income). An algorithm called an inducer automatically builds a regressor from a training set.

When a regressor is generated, MineSet also generates a visualization. This visualization can help you understand the regressor and how it makes predictions. In addition, it can provide valuable insight into the data itself. Once generated, a regressor can be used to predict the label value for unlabeled records.

The underlying structure used for regression is a Regression Tree, such as the one shown in Figure 15-1.

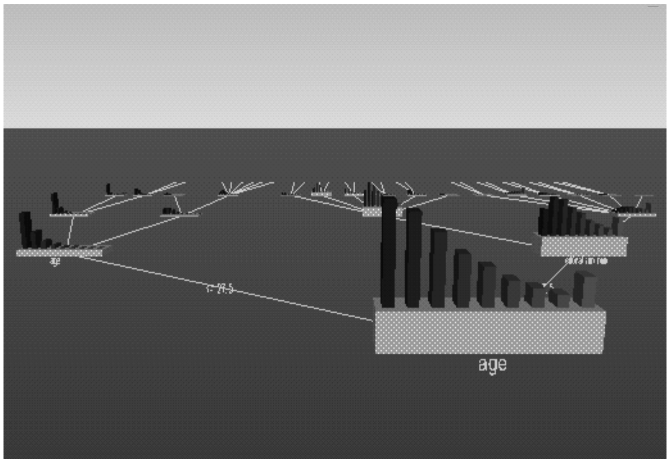


**Figure 15-1** Regression Tree for the Adult Dataset

## Running the Regression Tree Inducer

There are two ways to run the Regression Tree Inducer:

- From the Tool Manager.

  Connect to the server and select a data source (see “Choosing a Data Source” in Chapter 3).

  From the File menu, choose Open New Data File. Log in to a server, and enter the filename. For the example shown here, the filename entered would be */usr/lib/MineSet/data/adult.schema*. In the Continuous Label popup menu of the Data Destination pane you see a list of continuous attributes. Of the several continuous attributes available, one is automatically selected as the label option. You may change this. Regression Tree Inducer is automatically shown as the inducer. To run the Inducer, click *Go!*.

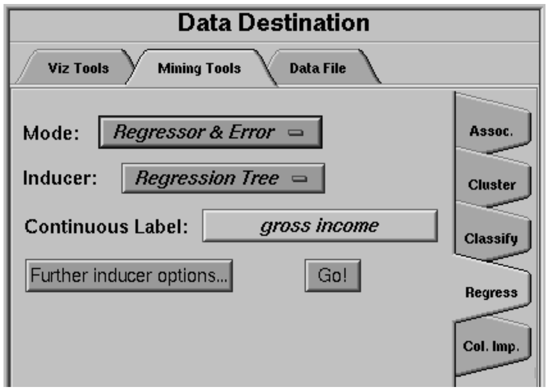
  The status window shows the progress and statistics, and the Tree Visualizer is launched automatically.

- From the command line.

  To induce a Regression Tree classifier from the command line, refer to Appendix I, “Command-Line Interface to MIndUtil: Analytical Data Mining Algorithms.”

## Configuring the Regression Tree Inducer Using the Tool Manager

To access the options for configuring the Regression Tree Inducer, select the Mining Tools tab on the Data Destination panel (Figure 15-2). From the tabs at the right, select Regress. The selected inducer is the Regression Tree, the only regression model currently available in MineSet. Your selections in the Mode menu determines the options available in the Further Inducer Options menu. After you have made your selections in these menus, click *Go!* to induce the regressor.



Mode: *Regressor & Error*
Inducer: *Regression Tree*
Continuous Label: *gross income*

**Figure 15-2** Data Destination Panel in Tool Manager Showing Regressors

### Continuous Label

The Continuous Label menu provides a list of possible continuous labels. This list includes all attributes that take on numeric values. Select the label attribute you wish to model. For instance, to generate a regressor for predicting gross income, select “gross income”. (See “Training Set” in Chapter 10). If there are no continuous attributes, the menu shows *No Continuous Label*, and the *Go!* button is disabled. Regressors can only be generated for continuous attributes. If the dataset does not contain a continuous attribute you may add a new continuous column using the Tool Manager’s Data Transformations panel.

## Regressor Name

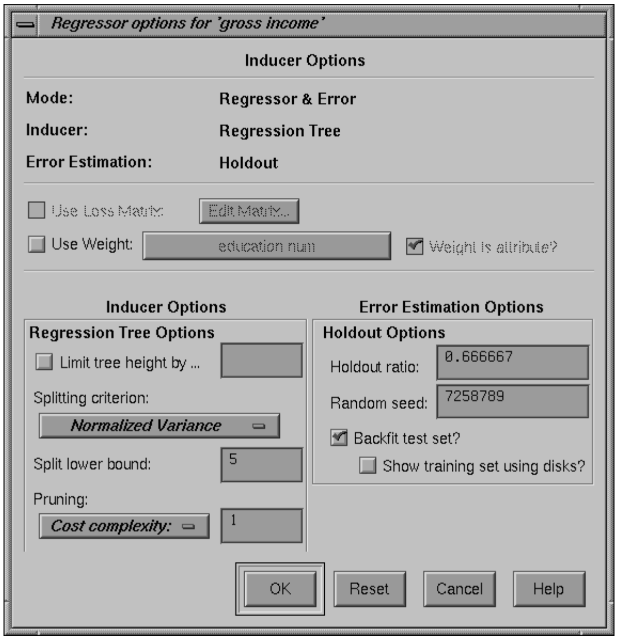
The generated regressor is named with the prefix of the session filename (as determined in Tool Manager) and the suffix *-rt.regress*. By default, all regressors are stored on the server in the *file_cache* directory, which defaults to *mineset_files*.

These regressors can be used to predict the labels for unlabeled datasets. To apply a stored regressor, you need to select a dataset of records with the attributes used by the regressor. The regressor will predict a new continuous label value for each record. See "Applying a Model" and "Backfitting in Error Estimation" in Chapter 10.

## Regression Tree Options

Selecting Further Inducer Options displays the Inducer Options dialog box (Figure 15-3). to appear. This dialog box consists of four panels:

- The top panel indicates the choices you made in the Tool Manager's Data Destination panel.
- The second panel from the top lets you set the weight attribute. See "Weight Setting" in Chapter 10.
- The bottom-left panel lets you specify other Inducer Options.
- The bottom-right panel lets you specify the Error Estimation Options (unless the mode you chose in the Data Destination panel was Classifier Only, in which case this area is empty). The options shown in this panel depend on the type of Error Estimation you chose (see "Error Options for Inducers" in Chapter 10).



Regressor options for 'gross income'

Inducer Options

Mode: Regressor & Error

Inducer: Regression Tree

Error Estimation: Holdout

□ Use Loss Matrix: Edit Matrix...

□ Use Weight: education num ☑ Weight is attribute?

Inducer Options

Regression Tree Options

□ Limit tree height by ...

Splitting criterion: Normalized Variance

Split lower bound: 5

Pruning: Cost complexity: 1

Error Estimation Options

Holdout Options

Holdout ratio: 0.666667

Random seed: 7258789

☑ Backfit test set?

□ Show training set using disks?

**Figure 15-3** Further Inducer Options

### Regression Tree Inducer Options

To fine-tune the Regression Tree induction algorithm, you can change the following Regression Tree Inducer options (see Figure 15-3).

- *Limit tree height by*

  By default, there is no limit to the height (number of levels) in the Regression Tree. You can limit the height by clicking the check box and typing a number for the limit. Limiting the number of levels speeds up the induction and is useful for studying the Regression Tree without the distraction of too many nodes. Note that restricting the size decreases the run time, but may increase the error rate. Setting this option does not affect the attributes chosen at levels before the maximum level.

- *Splitting criterion*

  This option allows you to specify which criterion will be used to select among competing attribute splits during tree induction. For regression trees, MineSet supports four splitting criteria:

  *Variance* chooses splits that minimize the within-node variance at each point in the tree. When generating a leaf, the prediction at the leaf is the mean of the label values of the records reaching that leaf. Variance is the squared difference between each of the values in the set, divided by the total number of elements or values. This mode is most commonly used statistically.

  *Absolute Deviation* chooses splits that minimize the absolute deviation within the node at each point in the tree. When generating a leaf, the prediction at the leaf is the median of the label values of the records reaching that leaf.

  *Normalized Variance* (the default) is variance divided by the log (base 2) of the number of child nodes.

  *Normalized Absolute Deviation* is absolute deviation divided by the log (base 2) of the number of child nodes.

  For a given problem, it is difficult to know which criterion will be best. Try each, and select the one that leads to the lowest error estimate, or the Regression Tree you find easiest to understand.

- *Split lower bound*

  This is a lower bound on the weight (or the number of records if weight was not set) that must be present in at least two of the node's children. The default for this option is 5. For example, if there is a three-way split in the node, at least two out of the three children must have a weight of five or more. This provides another method of limiting the size of the Regression Tree.

  Increasing the split lower bound tends to increase the reliability of the probability estimates, because the number of records at each leaf is larger. It also creates smaller trees and decreases the induction time. If you expect the data to contain noise (errors or anomalies), increase the split lower bound. If your dataset is very small (< 100 records), you might want to decrease the split lower bound.

- *Cost Complexity Pruning*

  Cost complexity pruning attempts to generate optimally sized trees by trading off the error rate of the tree (its cost) and the number of leaves in the tree (its complexity). During cost complexity pruning the training set is partitioned into a learning set and a pruning set. The learning set is used to grow a pruning tree. This tree is pruned to generate a sequence of trees with decreasing complexity. The pruning set is then used to identify the minimum cost tree in this sequence. The size of the minimum cost tree is noted. The learning and pruning sets are recombined and used to grow a tree. This tree is then pruned to the size of the minimum cost tree.

  The cost complexity pruning parameter allows you to select trees smaller than the minimum cost tree. The parameter indicates the number of standard errors more costly than the minimum cost tree that you are willing to accept. Setting the parameter to zero selects the minimum cost tree; setting the parameter to 0.5 selects the minimum size tree that had an error rate no more than 0.5 standard errors worse than the minimum cost tree. The default setting, 1, selects the minimum size tree that has an error rate no more than one standard error worse than the minimum cost tree. Higher numbers indicate more pruning. If your data may contain noise (errors and anomalies), increase the number to create smaller trees. If the tree is pruned back to a single node, decrease the number to decrease the amount of pruning and show more of the trees structure.

  Pruning is slower than limiting the tree height or increasing the split lower bound because a full tree is built and then pruned. Pruning, however, is done selectively, resulting in a more accurate regressor.

## Error Estimation

When evaluating a classifier the natural metric is error (the number of examples for which the classifier predicts the wrong label). When a loss matrix is supplied, different types of misclassification errors may have different associated costs. In this situation loss is a natural measure.

For regression, where the task is to predict a real value there is no single natural evaluation metric. The two measures that are frequently used are *mean squared error* and *mean absolute error*. In Mean Squared Error, the mean of the squared difference between the predicted label value and the actual label value is used. In mean absolute error, the mean of the absolute value of the difference between the predicted label value and the actual label value is used.

## Visualizing the Regression Tree

A Regression Tree visualization is similar to Decision Tree visualization. Like a Decision Tree, a Regression Tree consists of nodes connected by lines (see Figure 15-1).

There are two types of nodes: decision nodes and leaf nodes.

### Decision Nodes

Decision nodes specify the attribute that is tested at the node. Values (or ranges of values) against which the attributes are tested are shown at the lines. Each possible value for the attribute matches exactly one line. For example, the root of the Regression Tree in Figure 15-1 tests the attribute age; the two lines emanating from the node partition values for that attribute (< 27.5, => 27.5) so that every possible value matches either the right branch or the left branch. If the value is unknown and there is no line labeled with a question mark, the mean or median label values at the current node is predicted.

### Leaf Nodes

Leaf nodes in a Regression Tree predict a value. Follow the left-most branch in Figure 15-1 from the root to the leaf labeled 5540.038. Note that the Regression Tree predicts that people under 23.5 who work less than 35.5 hours per week will average a gross income of $5540.40.

### Node Information

The bars atop nodes in a Regression Tree are different than the bars atop nodes in a Decision Tree. In a Decision Tree each bar corresponds to a specific discrete label value. In a Regression Tree each bar corresponds to a subrange of continuous label values. In a Decision Tree the bars have a simple mapping throughout the entire tree. For example, in Figure 11-1 of Chapter 11, “Inducing and Visualizing the Decision Tree Classifier,” the leftmost bar of each node indicates the weight (number) of records with the iris-setosa label. By contrast, in a Regression Tree the range of continuous label values covered by each node can be different. The bars at each node form a histogram indicating how the weight (number) of records is distributed over this range. The leftmost bar always shows the weight (number) of records with the lowest label values. But the size of that subrange and its midpoint maybe different at every node. In a Decision Tree, the color of a bar indicates the discrete class label. In a Regression Tree, the color of a bar indicates the midpoint of the subrange that bar covers.

In the Decision Tree, each bar corresponds to a label value. The height of the bar indicates the total weight of records with that label value at that node. The bars are consistent throughout the entire tree. For example, if you run the Regression Tree on the iris dataset the leftmost bar at the root node indicates the weight (number) of records with the iris-setosa label. The left most bar at each node indicates the weight (number) of records with the label iris-setosa.

In a Regression Tree, the set of bars on a node collectively form a histogram of the label values at that node. The number of bars is determined by the weight of records at the root. The color of the bars indicates of the range. The maximum range is indicated by blue on the left and red on the right. A node which only covers records with a limited range of label values will have a histogram that doesn’t range from blue to red.

The base of each node has a height. The height corresponds to the weight of the training set records that have reached this node (this is the number of records if weight was not set). In general, the higher the weight, the more reliable the distribution at a node.

Pointing to a node causes the following information to be displayed:

- *Subtree weight*—The weight of the training set records in the subtree below the node pointed to. This value is mapped to the height of the base.
  - *Mean*: the mean of the continuous label
  - *Standard deviation*: the standard deviation of the continuous label. The higher the standard deviation, the less reliable the model.
  - *Median*: the median of continuous label.
  - *Absolute deviation*: absolute deviation of the continuous label. The higher the absolute deviation, the less reliable the model.

## Lines

All possible outcomes are marked on the horizontal lines emanating from each decision node. Each line indicates the value (or range of values) against which the attribute of that node was tested.

## Using the Main Window to Predict Values

To predict a value for a record, start at the root, and test how to branch at every decision node. By following the appropriate lines based on the record’s attribute values, you reach a leaf node. The label, or prediction, associated with the leaf node is the predicted value of the record.

## External Controls

The external controls for the visualizer associated with a Regression Tree are the same as those for the Tree Visualizer. For a description of these controls, see “External Controls” in Chapter 5.

One particularly useful control for regression trees is to select a node, and from the menu Selections select the menu item Normalize Sub Tree (or press Ctrl-N). This will normalize the height and color range of the tree using the current node. By default the tree is normalized to the root node.

Another useful control is to click the right mouse button when pointing to a node. This shows the list of children of that node.

## Pulldown Menus

The pulldown menus for the visualizer associated with a Regression Tree are the same as those for the Tree Visualizer. For a description of these menus, see “Pulldown Menus” in Chapter 5, and “The Search and Filter Panels” in Chapter 11.

## Sample Files

The following examples show cases in which regression might be useful and highlight some of the capabilities of the Regression Tree Inducer. Each of these examples is associated with a sample data file provided with MineSet. By running the inducer, you can generate the *-rt.regress files* described below.

**Note:** The data files, which have a *.schema* extension, are located in */usr/lib/MineSet/data* on the client workstation; and the regressor visualization files, with a *-rt.treeviz* extension, reside on the client workstation in */usr/lib/MineSet/treeviz/examples*.

### Churn

The *churn* dataset contains generated information on the calling patterns of a telecommunication company's customers. In the classification examples, this dataset is used to determine which factors lead a customer to churn, or leave the company for one of its competitors. In this regression example, we will try to determine what factors influence how much the company charges each customer per day.

The file *churn-rt.treeviz* shows the Regression Tree generated on this data set to predict the total day charge. Interestingly, the tree branches on only one attribute throughout, total day minutes, continuously dividing this attribute further and further into progressively smaller ranges. This is because the relationship between total day minutes and total day charge is completely deterministic—the customers are charged only for the minutes they use the system. The Regression Tree is quickly able to locate and capitalize on this fact.

### Car Mileage

The *cars* dataset contains information about different models of cars from the 1970s and the early 1980s. Attributes in this data set include weight, acceleration and miles per gallon. The file *cars-rt.treeviz* shows the Regression Tree regressor induced on this data set, using miles per gallon as the continuous label.

By clicking on the top node, we see that the average mpg of cars in this dataset is around 23.5. The first split in the Regression Tree for this dataset shows that the most important factor contributing to the mileage of a car is its weight. The Regression Tree has discovered that heavier cars get lower mileage, a fact that may be obvious to a human observer, but is insightful for an automated discovery program. By looking at the two children of the base node, we note that the right child is bluer than the left one, that is it gets fewer miles per gallon. By highlighting the nodes, we see that cars that weigh less than 3018 lbs. get around 28.3 mpg, while cars weighing more get around 16.6 mpg.

Heading over to the heavier cars, we see that the next split is on the horsepower of the car, and that more powerful cars tend to get lower mileage. The split at the next level that is on the year the car was made, with newer cars getting better mileage. Now, let's look for an unusual car. Using the filter panel, let's try and find a node with a mean mpg < 24 but with a maximum > 30. Doing this filter, we quickly reduce the tree to one node, cars weighing less than 3018 lbs, with more than 77 horsepower, and made before 1980. In this category, there is an unusual car; by selecting the rightmost bar on that node and sending this information to the Tool Manager via the Selections > Show Original Data menu item, we see that this car is a 1978 Dodge, weighing around 2000 lbs, with 83 hp, but getting a high 33.5 miles per gallon.

### Salary Factors

The *adult* dataset contains information about working adults, extracted from the U.S. Census Bureau. It contains data about people older than 16, with a gross income of more than $100 per year, who work at least one hour a week. We can use the Regression Tree Inducer to determine which factors influence a person’s salary; as well as to give a rough prediction of what that person’s salary would be, given the other information.

The file *adult-rt.treeviz* shows the Regression Tree regressor induced on the adult dataset, using gross income as the continuous label. Note that this data set is large (around 50000 records), and therefore inducing the regressor on this data set may take a few minutes on your workstation.

The bars at the top node provide a histogram of salary values in the Census Bureau’s data. Note that the amount of data available decreases as the salary level increases. We have a lot of data for people earning around $3,000 a year, but less so as that figure increases. This trend is reversed in the last part of the histogram that indicates a sizeable amount of data on people earning roughly $100,000 per year. This discrepancy might be the result of either a genuine trend in the data, or a biased sampling.

The first division in the Regression Tree is on the age attribute. As expected, younger people generally make less money than older people. Brushing the top node and its two children nodes, we can see some summary statistics for these three groupings of people. We note that the mean salary for everyone in this study is around $33,500, while the mean salary of people under 27 is around $14,300; and the mean salary of those over 27 is around $40,000.

Following the next two divisions of people under 27, we see that the tree again splits them into two categories: those 23 and under, and those over 23. Interestingly, the split past these two divisions is the same, and on the hours per week attribute, indicating that for both age ranges the more hours worked, the higher one’s gross income.

Now, focusing on those over 27, we find that the tree splits immediately on the amount of education a person has had. Those with an education number 13 and over (which corresponds to a bachelor’s degree), tend to make more money. By looking over the two children of the education number split, we can see that most of the people making around $90,000 a year have at least some advanced education.

We can use the filter panel, to quickly locate those categories of people making on average over $50,000 a year. In the filter panel, select mean > 50000. Top level nodes disappear in this filter, as making that amount of money is a rare occurrence. People with a bachelor’s degree who are over 27 fall in this category. By following the left branch of the first split to the end, we find another group of people in this category: married men over 36 years old, who work over 35 hours a week and have a good education (10 years or more).

If we revisit the filter, and look for nodes with an absolute deviation of larger than $25,000, we can find those people whose economic condition offers the widest variability. The first remaining node in this filter is those people over 27 and with a bachelor’s degree. The histogram above this node shows a distribution centered around its mean, but with an unusual number of people making around $100,000 a year.

### Iris

Each record in this dataset describes five characteristics of iris flowers, petal width, petal length, sepal width, sepal length, and iris type. Our goal in this regression is to predict the petal width based on the other characteristics. The file *iris-rt.treeviz* shows the results of the Regression Tree Inducer run on this dataset in order to predict petal width.

Looking at the top node, we see a gap in the petal width values, where no flowers exist. The Regression Tree Inducer splits on this data set first using the petal length variable. If the petal length is less than 2.6, only a restricted set of petal widths seems possible. On the other hand, petal length values greater than 2.6 indicate a more even distribution with larger corresponding petal lengths. The mean petal width for those irises with petal lengths less than 2.6 is 0.24, while the corresponding mean petal width for those with lengths greater than 2.6 is 1.68. Following the large petal length irises, we see that the tree splits again on petal length, this time on the value 4.85. These two consecutive splits on the same variable point to some kind of restricted functional relationship between these two variables.

Going back to those irises with a petal width less than 2.6, we see that the following split is on the sepal width attribute. Interestingly, the values in this part of the tree seem segregated, with those irises with sepal width less than 3.25 taking on values in three narrow but separated ranges.

### Pima

This dataset is a diabetes diagnosis problem using statistics gathered from an Indian tribe in Phoenix, Arizona. The file *pima-rt.treeviz* shows the results of running the Regression Tree Inducer on this dataset, using the plasma glucose level as the predicted continues variable.

The first split in this tree is on the diabetes indicator, showing that people with diabetes tend to have a higher plasma glucose level than those without (141 versus 110). The next split is the 2-hour serum insulin attribute, where values greater than 125 lead to higher plasma glucose.

The Regression Tree predicts by following the decisions at each of the nodes from the top node, while examining new records. For example a diabetic patient with 2-hour serum insulin of 110 would have a predicted plasma glucose level of 105.

*Chapter 16*

# Inducing and Visualizing Clustering

This chapter discusses the features and capabilities of the Clustering mining tool, and the selection of parameters by which to run clustering in relationship to the other data mining tools. Sample files, provided with MineSet, is discussed at the end of this chapter.

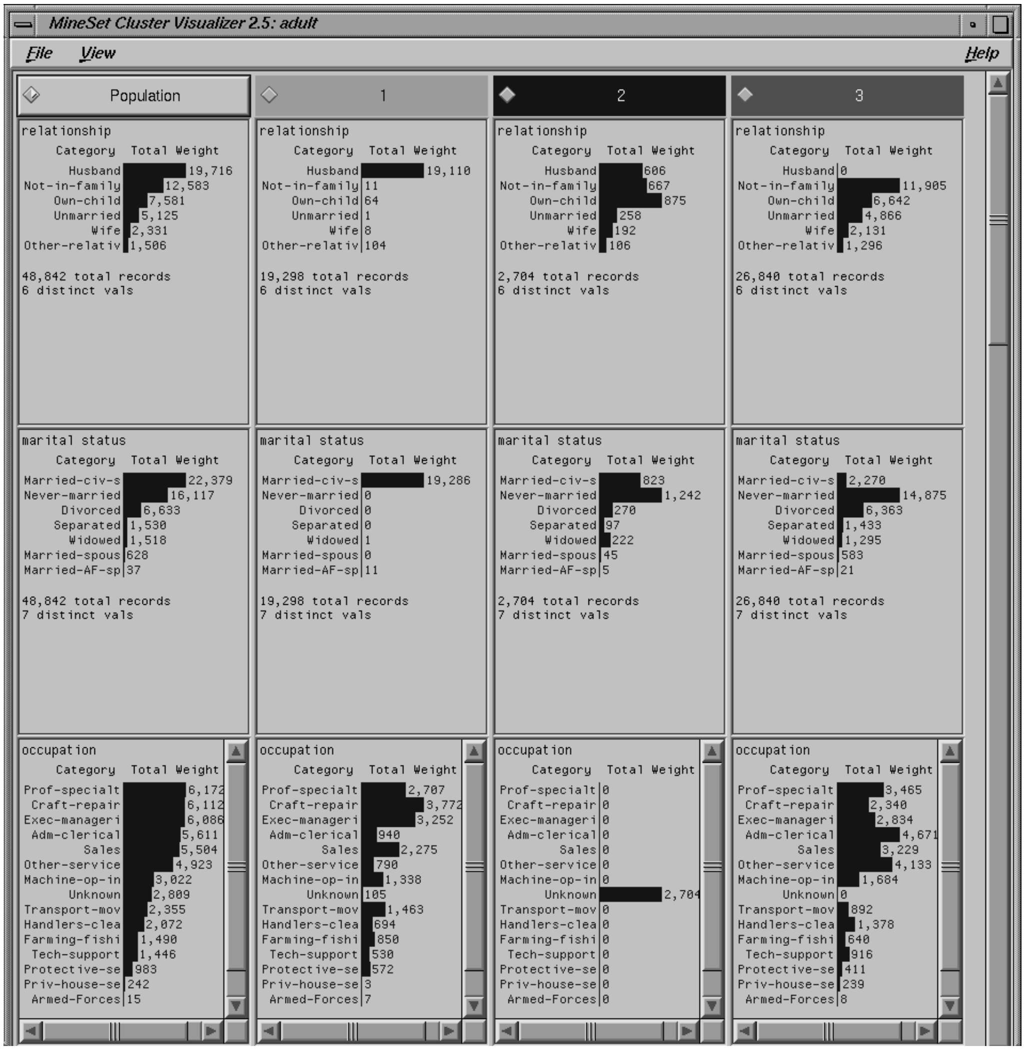
**Note:** This chapter assumes that you have read Chapter 10, “MineSet Inducers and Classifiers.”

## Overview of Clustering

The Clustering mining tool is useful for exploring a dataset which is not well known. Because clustering is a descriptive mining task similar to the discovery of association rules, you do not need to designate a specific column as a label. In addition, the dataset is never split into training and test sets; clustering models are always built from an evaluated on the full dataset.

A clustering model is stored as a set of prototypical records, one per cluster. These represent a weighted average of all data in the cluster and are known as *Cluster centers* or *centroids*. Unlike standard database records, Cluster centers maintain a distribution for each column in the form of summary statistics for numerical columns or histograms for categorical columns.

Once the clustering operation has been run, you can view the Cluster centers directly using the Cluster Visualizer as shown in Figure 16-1. Alternatively, you can use the apply model facility (see “Applying a Model” in Chapter 10) directly on the training data to assign a cluster to each record. You can then use many of the other tools in MineSet to explore the resulting clusters.



| relationship | Population | 1 | 2 | 3 |
|---|---|---|---|---|
| Category | Total Weight | Total Weight | Total Weight | Total Weight |
| Husband | 19,716 | 19,110 | 606 | 0 |
| Not-in-family | 12,583 | 11 | 667 | 11,905 |
| Own-child | 7,581 | 64 | 875 | 6,642 |
| Unmarried | 5,125 | 1 | 258 | 4,866 |
| Wife | 2,331 | 8 | 192 | 2,131 |
| Other-relativ | 1,506 | 104 | 106 | 1,296 |
| | 48,842 total records<br>6 distinct vals | 19,298 total records<br>6 distinct vals | 2,704 total records<br>6 distinct vals | 26,840 total records<br>6 distinct vals |

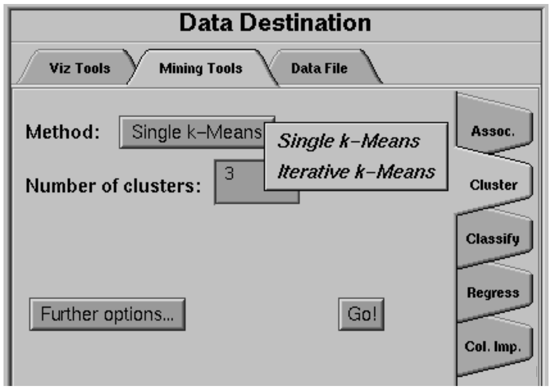
| marital status | Population | 1 | 2 | 3 |
|---|---|---|---|---|
| Category | Total Weight | Total Weight | Total Weight | Total Weight |
| Married-civ-s | 22,379 | 19,286 | 823 | 2,270 |
| Never-married | 16,117 | 0 | 1,242 | 14,875 |
| Divorced | 6,633 | 0 | 270 | 6,363 |
| Separated | 1,530 | 0 | 97 | 1,433 |
| Widowed | 1,518 | 1 | 222 | 1,295 |
| Married-spous | 628 | 0 | 45 | 583 |
| Married-AF-sp | 37 | 11 | 5 | 21 |
| | 48,842 total records<br>7 distinct vals | 19,298 total records<br>7 distinct vals | 2,704 total records<br>7 distinct vals | 26,840 total records<br>7 distinct vals |

| occupation | Population | 1 | 2 | 3 |
|---|---|---|---|---|
| Category | Total Weight | Total Weight | Total Weight | Total Weight |
| Prof-specialt | 6,172 | 2,707 | 0 | 3,465 |
| Craft-repair | 6,112 | 3,772 | 0 | 2,340 |
| Exec-manageri | 6,086 | 3,252 | 0 | 2,834 |
| Adm-clerical | 5,611 | 940 | 0 | 4,671 |
| Sales | 5,504 | 2,275 | 0 | 3,229 |
| Other-service | 4,923 | 790 | 0 | 4,133 |
| Machine-op-in | 3,022 | 1,338 | 0 | 1,684 |
| Unknown | 2,809 | 105 | 2,704 | 0 |
| Transport-mov | 2,355 | 1,463 | 0 | 892 |
| Handlers-clea | 2,072 | 694 | 0 | 1,378 |
| Farming-fishi | 1,490 | 850 | 0 | 640 |
| Tech-support | 1,446 | 530 | 0 | 916 |
| Protective-se | 983 | 572 | 0 | 411 |
| Priv-house-se | 242 | 3 | 0 | 239 |
| Armed-Forces | 15 | 7 | 0 | 8 |

**Figure 16-1** Clustering Visualization on Adult Dataset

Clustering is run from the Mining tab in the Data Destinations panel of Tool Manager. The purpose of clustering is to determine what if any characteristics in the dataset are similar. You then look at the resulting clusters and experiment with different parameters.

All clustering in MineSet uses a combinatorial algorithm based on the k-means objective function; the algorithm forms clusters by grouping similar records together, aiming to maximize the overall similarity within each group. MineSet provides two distinct modes of clustering, single and iterative, both of which are discussed below.



Method: Single k–Means

Number of clusters: 3

**Figure 16-2** The Clustering Tab

There are two methods of clustering

- Single k-means

  The term *k-means* refers to the objective function determining possible good clustering based on similarity between records.

- Iterative k-means

  This method requires three parameters: a lower boundary, an upper boundary, and a choice point. The algorithm will pick a number of clusters somewhere between the lower and upper boundary which is appropriate for the dataset. The choice point is a value between zero and one which guides the selection of the number of clusters; higher choice points suggest larger numbers of clusters while lower choice points suggest smaller numbers. A choice point of 1.0 will always pick the upper boundary. For example, if your boundaries are one and five clusters, a choice point of 0.4 might pick two clusters while a choice point of 0.8 will pick four. A choice point of 1.0 will always pick five.

## Using Clustering and the Cluster Visualizer

Select the Mining Tools tab in the Data Destination panel of the Tool Manager main window. From the subsequent tabs select Cluster. This will expose the main clustering panel.

You can begin the clustering process by clicking *Go!* from the main Cluster panel (see Figure 16-2; there are no required options. By default, you will use the single k-means clustering method to discover three clusters in the data. Once the clustering is complete, you will see an evaluation of the clustering (see "Evaluation of Clustering" on page 485), and then the Cluster Visualizer will appear. The Cluster panel provides the following options:

- Method—Allows you to choose between the single k-means and iterative k-means methods. The default is single k-means. Both methods are described in detail below.
- Number of clusters—For the single k-means method only, you must specify the number of clusters to find. The default is 3.
- Number of clusters range—For the iterative k-means method only, you must specify lower and upper bounds on the possible number of clusters. The default is 1 ... 10.
- Choice point—For the iterative k-means method only, you must specify a *choice point*. This is a value between 0 and 1 which helps choose the final number of clusters. See "Iterative k-Means Clustering Method" on page 484**.** The default is 0.5.

**Note:** Clustering is a computationally intensive operation and will take some time to complete on larger datasets, especially when running iterative k-means mode. We suggest clustering a sample of the data if your dataset has more than 10000 records.

## Single k-Means Clustering Method

This method is the simplest form of clustering in MineSet. You specify the desired number of clusters, and the algorithm groups the records in the data to minimize the overall dispersion within each cluster. Dispersion refers to the cohesiveness of a cluster; the higher the dispersion, the farther each record falls from the cluster center. Technically, dispersion is measured as the root mean squared distance from each record to the center of the cluster to which it is assigned.

The algorithm itself is iterative and proceeds as follows:

1. You select, for example, five clusters to find.
2. The five cluster centers are initialized to be in random positions in the space of all records. Different choices of the random seed parameter will produce different starting positions.
3. Each record in the data is assigned to the cluster whose center is closest to it. The cluster centers are then recomputed based on the new data in each cluster.

   The next step is run repeatedly until no improvement can be made:
4. If there are any records which are closer to the center of a different cluster than they are established in already, these records are moved to the closer clusters. Then the cluster centers are recomputed based on the new data in each cluster.

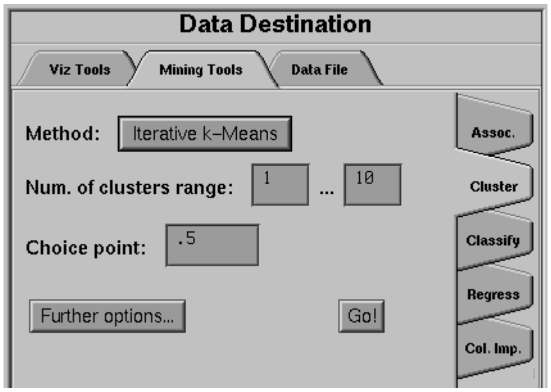
This algorithm is guaranteed to terminate in a finite number of iterations.

Step 4 dominates the running time of clustering. Therefore, the progress window will show one progress bar for each run of step 4, combined with a note on how many iterations have been run so far. You can set a limit on the maximum number of iterations (runs of step 4) allowed before the algorithm stops. The default is 20.

Clusters are assigned sequential numerical names starting from 1. Although cluster names are represented by numbers, there is no ordering to the clusters.

## Iterative k-Means Clustering Method

The iterative k-means clustering method is a more complex extension to the single k-means clustering method. Unlike single k-means, it does not require the specification on an exact number of clusters to create.



Data Destination

Method: Iterative k–Means

Num. of clusters range: 1 ... 10

Choice point: .5

**Figure 16-3** Clustering Using Iterative K-Means

To run iterative k-means, you select three parameters: a lower bound on the number of clusters (default 1), an upper bound on the number of clusters (default 10), and a choice point (default 0.5). See Figure 16-3. Given these parameters, the algorithm proceeds as follows:

1. Use the minimum number of clusters for a run of the single k-means algorithm. This will produce an initial clustering.

   The next steps are run repeatedly until the maximum number of clusters has been reached:

2. Find the cluster with the greatest dispersion and split it in half, creating two new clusters. Half of the records in the original cluster will be distributed to one of the new clusters and the other half will be distributed to the other new cluster. Recompute the centers of the new clusters based on the data they contain.
3. If there are any records which are closer to the center of a different cluster than that they are currently in, those records are moved to the closer clusters. The cluster centers are then recomputed based on the new data in each cluster. This is the same as step 4 of the single k-means method. As in the single k-means algorithm, this step is repeated until either no records need to be moved or until it has been run the maximum number of times allowed, as determined by the maximum iterations parameter (default 20).

This process has the effect of producing a range of clusterings between the minimum and maximum numbers of clusters.

The final clustering you are presented with is determined using the choice point parameter (default 0.5) as follows:

Each clustering is evaluated by measuring the average dispersion of each cluster. As the number of clusters increases, the average dispersion always decreases. However, it does not decrease uniformly. The choice point selects the desired degree of dispersion, measured as the proportion from the dispersion of the minimum number of clusters to the dispersion of the maximum number of clusters. The clustering with a measured dispersion closest to this value is chosen as the final clustering. Note that a choice point of 1.0 will always pick the maximum number of clusters, and a choice point of 0.0 will always pick the minimum.

Clusters are named based on their derivation during the splitting process. The initial clustering (based on the minimum number of clusters) is named using sequential numbers, just as in single k-means. Every time a cluster is split, the two new clusters are given the name of the split cluster, but with an "A" or a "B" appended. For example, the cluster named "2-B-A" was derived from cluster 2 in the initial clustering, and was split twice. We built three clusters using the single k-means algorithm with all default options except that we set the attribute weight for iris_type to zero.

## Evaluation of Clustering

When a clustering model is built, you will be presented with the following display of statistics in the status window:

This example is from the iris dataset, available in */usr/lib/MineSet/data.*

```
Result of clustering:
----------------------------------------
Overall root-mean-squared distance from record to centroid: 0.216 +-
0.0928 RMS distance from records to each centroid:
   Cluster 1: 0.2306 +- 0.09484
   Cluster 2: 0.1921 +- 0.09932
   Cluster 3: 0.2247 +- 0.08058
Model saved as iris.cluster
```

The numbers are measures of the dispersion of each cluster, as well as the overall excellence of fit of the clustering, dispersions from clusterings based on different datasets or different numbers or different numbers of clusters are not immediately comparable.

### Using Attribute Weights

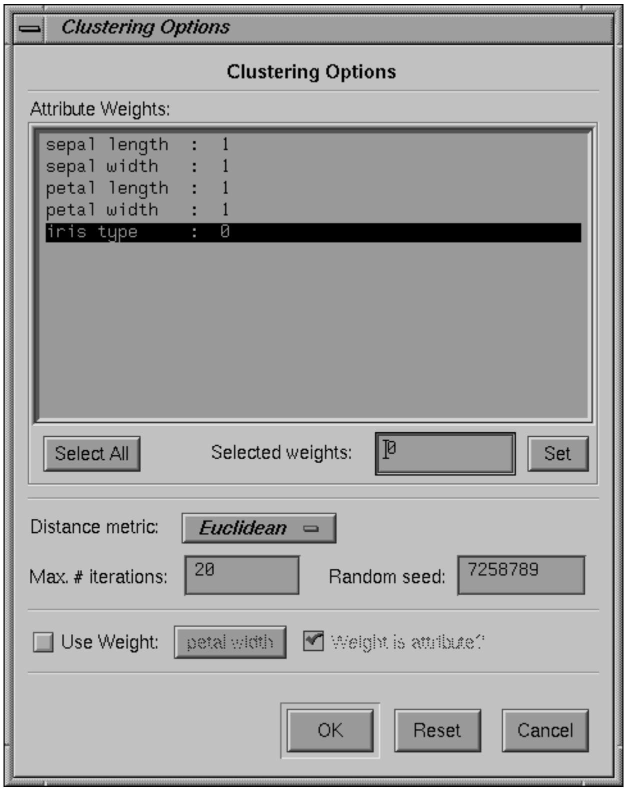
The k-means clustering algorithm relies on computing the distance between records and the center of a cluster. Each column in the data is treated as a separate dimension in a multi-dimensional space of all records. By default, each column in the data has an equal influence on the final distance. However, you may change the influence of each column, or attribute, by specifying *Attribute Weights* in the Clustering Options dialog box for clustering, see Figure 16-4.

The attribute weight of a column is a value greater than or equal to zero, which determines the column's influence in the distance computations of the clustering algorithm. Setting an attribute's weight to 1 gives it an average influence. Setting it to 2 gives it the influence of two copies of exactly the same column. Setting it to 0 causes the column to have no effect on the clustering (the clustering proceeds as if you had removed the column from the data before running clustering). Attribute weights need not be integral and may be less than one.

To set attribute weights, first click on the *Further options* button in the main clustering panel. The top portion of the Further Options dialog box (illustrated in Figure 16-4) shows the current attribute weights, which all default to 1. To change one or more weights, select the column(s) whose weights you wish to change (use Shift-click to select or deselect a range, and Ctrl-click to select or deselect more than one value at once). Now type the new weight value into the Selected weights field. Finally, click the *Set* button and the selected weights will change to the new value. You may select and set all weights at once using the *Select All* button.

You will need to adjust attribute weights to help discover a more understandable clustering. Guidelines for weighting are:

- String or enum type columns with large numbers of values should generally get low weight (often 0). While such columns will heavily skew the clustering if used by the algorithm, they can help explain the clustering later.
- If you have detected several columns which correlate strongly, adjust the weights so that the TOTAL WEIGHT of this set of columns is 1. Otherwise these columns may excessively drive the clustering.
- Since distances between categorical (string or enum) columns tend to be greater, it is often useful to give them lower weights than real-valued columns.



Clustering Options

Attribute Weights:

```
sepal length  :  1
sepal width   :  1
petal length  :  1
petal width   :  1
iris type     :  0
```

Selected weights: 0

Distance metric: Euclidean

Max. # iterations: 20

Random seed: 7258789

□ Use Weight: petal width

☑ Weight is attribute?

**Figure 16-4** Clustering Options Dialog Box

## Further Clustering Options

- *Attribute Weights*

  Clustering gives the opportunity to weight the value of each attribute in the dataset differently. See “Using Attribute Weights” for more information about this option.

- *Distance Metric*

  This metric determines the way in which distances between records and cluster centers should be measured. The default choice is Euclidean distance, which measures distance along a straight line in multidimensional space, with one dimension per column in the data. The popup menu provides an alternate choice, Manhattan. Manhattan distance is computed by adding the distance along the axis of each dimension. This metric gets its name from the way one traverses street blocks in Manhattan: it is not possible to go straight from point A to point B because travel may only proceed along paths parallel to the axes (streets).

- *Max. # Iterations*

  This option sets a limit on the number of passes through the dataset the clustering algorithm may use. More specifically, it limits the number of runs of Step 4 in the single k-means algorithm. See the section on the k-means method.

- *Random Seed*

  Different random seeds will result in different starting points for the initial cluster centers. See the section on the k-means method.

- *Use Weight*

  Like most mining tools in MineSet, Clustering supports record weights. This option allows you to specify a column (which must have a numerical value) which will specify the weight of each record in the data.

- *Weight is Attribute*

  If this box is selected, the designated weight column will also be used as a normal attribute by the clustering algorithm. If this box is unchecked, the designated weight column will not be used as an attribute; it will also disappear from the attribute weights section (it is given an implicit weight of zero).

## Starting the Cluster Visualizer

There are six ways to start the Cluster Visualizer:

- Use the Tool Manager to configure and start the Cluster Visualizer. (See Chapter 3 for details on most of the Tool Manager's functionality, which is common to all MineSet tools; see "Working in Cluster Visualizer Main Window" on page 490 for details about using the Tool Manager with the Cluster Visualizer.)
- Double-click the Cluster Visualizer icon, which is in the MineSet page of the icon catalog. The icon is labeled *clusterviz*. Since no configuration file is specified, the start-up screen requires you to select one by using File > Open.
- Double-click the Cluster Visualizer icon on your Silicon Graphics desktop. The startup screen requires you to select a data file by choosing File > Open.

  Starting the Cluster Visualizer without specifying a configuration file displays the copyright notice and license agreement for this tool. Only the File and Help pulldown menus can be used. For the main window to be fully functional, open a configuration file by choosing File > Open.
- If you know which configuration file you want to use, double-click the icon for that configuration file. This starts the Cluster Visualizer and automatically loads the configuration file you specified. This works only if the configuration filename ends in *.clusterviz* (which is always the case for configuration files created for the Cluster Visualizer using the Tool Manager).
- Drag the configuration file icon onto the Cluster Visualizer icon. This starts the Cluster Visualizer and automatically loads the configuration file you specified. This works even if the configuration filename does not end in *.clusterviz*.
- Start the Cluster Visualizer from the UNIX shell command line by entering this command at the prompt:

  ```
  clusterviz [ configFile ]
  ```

  *configFile* is optional and specifies the name of the configuration file to use. If you don't specify a configuration file, you must use File > Open to specify one.

### Options for Invoking the Cluster Visualizer

The **-quiet** option eliminates the dialogs that pop up to indicate progress. You can enable this option permanently by adding the line

```
*minesetQuiet:TRUE
```

to your *.Xdefaults* file.

## File Requirements

The Cluster Visualizer requires the following files:

- A data file consisting of rows of tab-separated fields. This file is easily created using the Tool Manager (see Chapter 3).

  You can generate data files by extracting data from a source (such as a database) and formatting it specifically for use by the Cluster Visualizer. Data files have user-defined extensions (the sample files provided with the Cluster Visualizer have *.clusterviz.data* extension)
- A configuration file, describing the format of the input data and how it is to be displayed. The Tool Manager can create this file (see Chapter 3), or you can use an editor (such as jot, vi, or Emacs) to produce this file yourself.

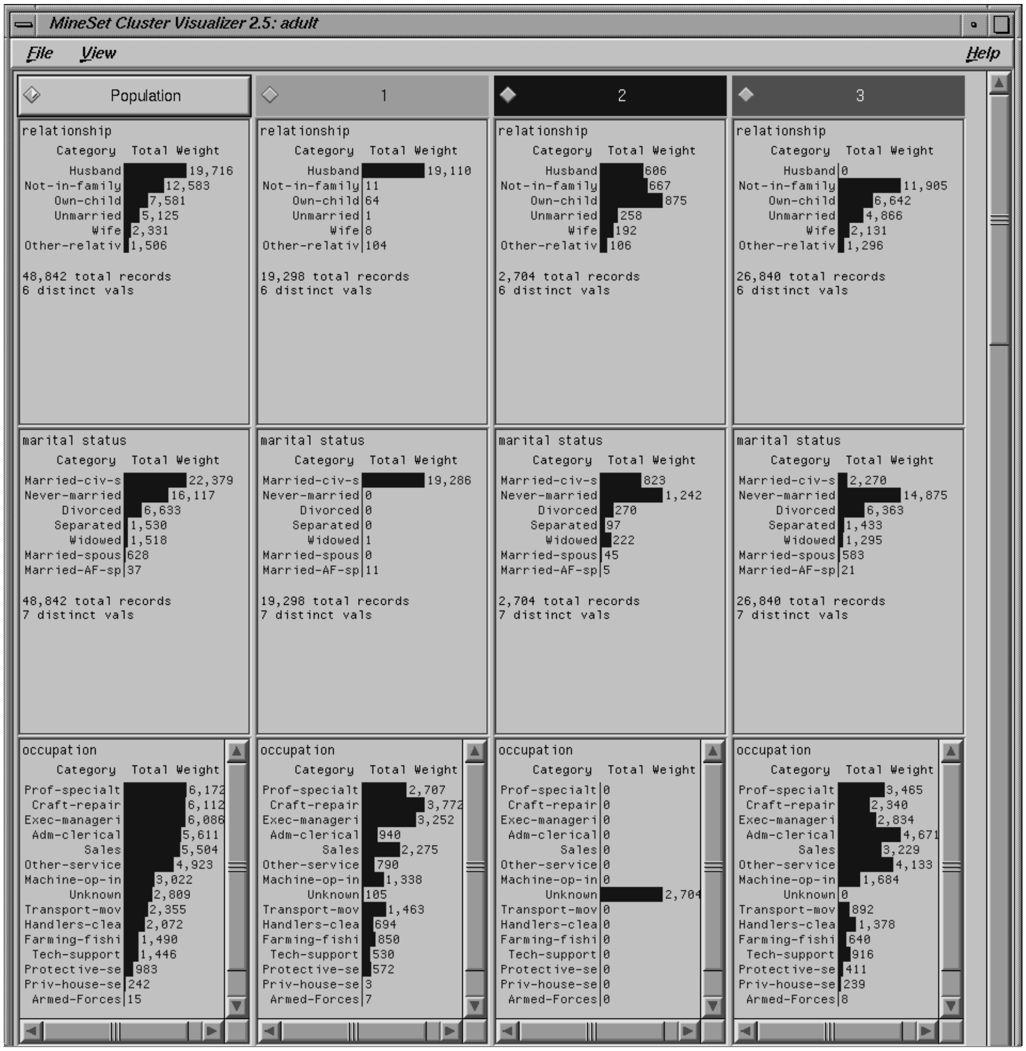
  Configuration files must have a *.clusterviz.*extension. When starting the Cluster Visualizer, or when opening a file, you must specify the configuration file, not the data file.

## Working in Cluster Visualizer Main Window

Cluster Visualizer illustrated in Figure 16-5 bears a resemblance to Statistics Visualizer (StatViz) with its box plots and histograms. Unlike in StatViz, the box plots are arranged in rows and columns. ClusterViz shows one row for each attribute in the data, and one column for each cluster. At the top of each cluster is a pane containing the name of the cluster. There is one additional column with the title “population”. This column displays statistics for the dataset as a whole and is equivalent to a StatViz view of the data.

Clusters are named based on the mode used to create them. Clusters created using single k-means are numbered sequentially. Clusters created using iterative k-means are numbered according to the process used to create them. In this example the clusters are simply numbered sequentially. The algorithm has no way of detecting what the clusters represent, and human interpretation is required. Each box plot shows statistics about data from a single column, including the minimum, maximum, mean, median, and two quartiles (25th and 75th percentiles). These values are shown as lines, and the standard deviation is shown as a value.

The order in which attributes are displayed in the Cluster Visualizer window is significant; by default, attributes are displayed in order of importance for discriminating between the clusters (this is the same importance ordering as shown in the Evidence Visualizer). Clicking on the pane containing the name of a cluster will redisplay the attributes in order of importance for discriminating that cluster from all others. Clicking on the pane containing “population” will restore the default ordering.



relationship

| Category | Population Total Weight | 1 Total Weight | 2 Total Weight | 3 Total Weight |
|---|---|---|---|---|
| Husband | 19,716 | 19,110 | 606 | 0 |
| Not-in-family | 12,583 | 11 | 667 | 11,905 |
| Own-child | 7,581 | 64 | 875 | 6,642 |
| Unmarried | 5,125 | 1 | 258 | 4,866 |
| Wife | 2,331 | 8 | 192 | 2,131 |
| Other-relativ | 1,506 | 104 | 106 | 1,296 |
| | 48,842 total records<br>6 distinct vals | 19,298 total records<br>6 distinct vals | 2,704 total records<br>6 distinct vals | 26,840 total records<br>6 distinct vals |

marital status

| Category | Population Total Weight | 1 Total Weight | 2 Total Weight | 3 Total Weight |
|---|---|---|---|---|
| Married-civ-s | 22,379 | 19,286 | 823 | 2,270 |
| Never-married | 16,117 | 0 | 1,242 | 14,875 |
| Divorced | 6,633 | 0 | 270 | 6,363 |
| Separated | 1,530 | 0 | 97 | 1,433 |
| Widowed | 1,518 | 1 | 222 | 1,295 |
| Married-spous | 628 | 0 | 45 | 583 |
| Married-AF-sp | 37 | 11 | 5 | 21 |
| | 48,842 total records<br>7 distinct vals | 19,298 total records<br>7 distinct vals | 2,704 total records<br>7 distinct vals | 26,840 total records<br>7 distinct vals |

occupation

| Category | Population Total Weight | 1 Total Weight | 2 Total Weight | 3 Total Weight |
|---|---|---|---|---|
| Prof-specialt | 6,172 | 2,707 | 0 | 3,465 |
| Craft-repair | 6,112 | 3,772 | 0 | 2,340 |
| Exec-manageri | 6,086 | 3,252 | 0 | 2,834 |
| Adm-clerical | 5,611 | 940 | 0 | 4,671 |
| Sales | 5,504 | 2,275 | 0 | 3,229 |
| Other-service | 4,923 | 790 | 0 | 4,133 |
| Machine-op-in | 3,022 | 1,338 | 0 | 1,684 |
| Unknown | 2,809 | 105 | 2,704 | 0 |
| Transport-mov | 2,355 | 1,463 | 0 | 892 |
| Handlers-clea | 2,072 | 694 | 0 | 1,378 |
| Farming-fishi | 1,490 | 850 | 0 | 640 |
| Tech-support | 1,446 | 530 | 0 | 916 |
| Protective-se | 983 | 572 | 0 | 411 |
| Priv-house-se | 242 | 3 | 0 | 239 |
| Armed-Forces | 15 | 7 | 0 | 8 |

**Figure 16-5** Cluster Visualizer Main Window

## Pulldown Menus

The Cluster Visualizer has three pulldown menus, labeled File, View and Help. These are similar to menus in the Evidence Visualizer (see“Pulldown Menus” in Chapter 13.)

## Sample File

The following example shows a case in which clustering might be useful. This example is associated with a sample dataset provided with MineSet. It shows how to work with the Clustering mining tool, and explains the different outcomes and options.

The cars dataset is relatively simple, dealing with familiar concepts of horsepower, vehicle weight, and time required to reach 60 mph.

In working with the Cluster Visualizer window, when you select cluster 1, that cluster controls the priority ordering of attributes represented by the bar charts and histograms. The order of attributes in other clusters is based on cluster 1. For example, if you click on cluster 1, the attribute importance is cylinders, weight, then miles per gallon. This ordering of importance is a controlling cluster only as far as the visualization goes. You can compare the same row across the other clusters to see how that attribute differs from cluster to cluster. When you select cluster 2, you see a differentiation in the order of attributes at a lower level. In this case, origin is more important, then cylinder, then horsepower, then miles per gallon.

## Alternative Visualization of Clustering

The Cluster Visualizer provides an easy-to-use basic visualization of the clustering. However, it is not the only way to visualize clustering. An example of transferring the results of clustering into a display using the Scatter Visualizer is shown in *MineSet 2.5 Tutorial*.

*Chapter 17*

# Column Importance

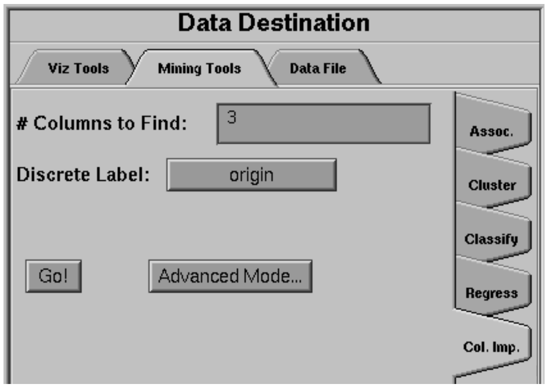
This chapter discusses the features and capabilities of the Column Importance mining tool, and the relationship between column importance and the importance ranking in the other data mining tools. Because of the differences in representation for classification models, different attributes may be judged more important for different models. A sample file, provided with MineSet, is discussed at the end of this chapter.

**Note:** This chapter assumes that you have read Chapter 10, "MineSet Inducers and Classifiers."

## Finding Important Columns

*Column Importance* is run from the tab labelled Col. Imp. on the Mining Tools panel (Figure 17-1). It determines how important various columns are in discriminating the different values of the label column you choose. You might, for example, want to find the best three columns for discriminating the label *good credit risk* so you can choose them for mapping to axes the Scatter Visualizer. When you select the label and click *Go!*, a popup window appears with the three columns that are the best three discriminators. A measure called "purity" (a number from 0 to 100) informs you how well the columns discriminate the different labels. Adding more columns can only increase the purity.

Purity is a measure of the skewness of the label value distribution. The cumulative purity measure is a measure of the purity of partioning the data. The data is partioned using columns found as importand in the same way data is partitioned in a Decision Tree. Each set in the partition has its own purity measure, and the purity measure within the partion is a combination of these individual measures. For a given set in the partition, the purity is 0 if each class has equal representation, and 100 if every record is of the same class. Similarly, the cumulative purity will be 0 if each set in the partition has an equal representation of classes, and 100 if each set in the partition contains record that all have the same class.



Data Destination

# Columns to Find: 3

Discrete Label: origin

**Figure 17-1** The Column Importance Tab

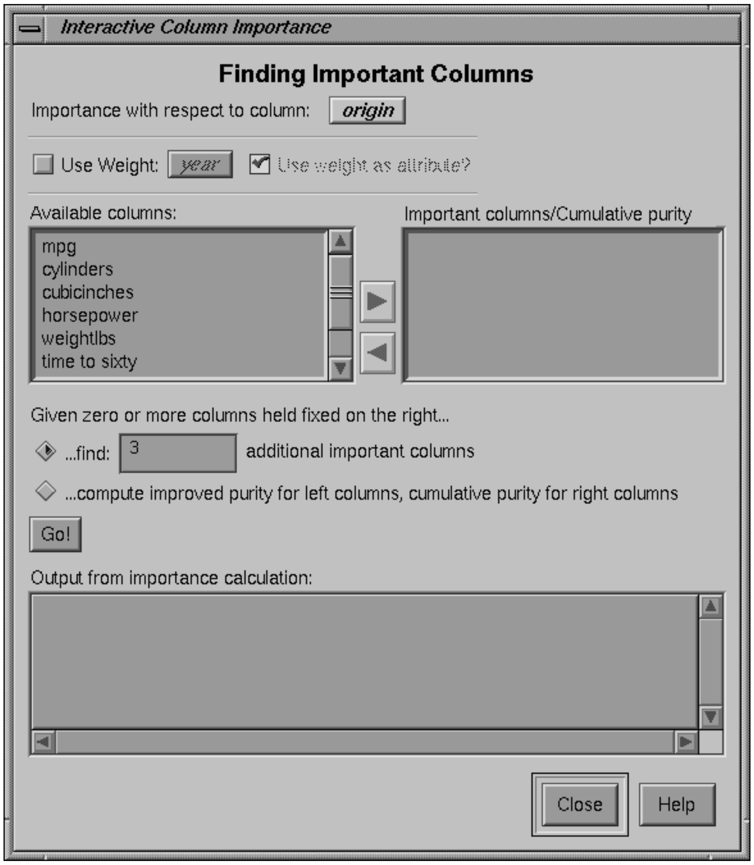
There are two modes of Column Importance:

- Simple Mode

  To invoke the Simple mode, choose a discrete label from the popup menu, and specify the number of columns you want to see, then click *Go!*.

- Advanced Mode

  Advanced mode lets you control the choice of columns. To enter Advanced mode, click *Advanced Mode* in the Column Importance panel. A dialog box appears, as shown in Figure 17-2. As with Further Inducer Options (see Chapter 10, “MineSet Inducers and Classifiers”), you can select a weight attribute and decide whether it behaves as a regular attribute for determining importance. The dialog box contains two lists of column names: The left list contains the available attributes and the right list contains attributes chosen as important (by either the user or the Column Importance algorithm).



Interactive Column Importance

Finding Important Columns

Importance with respect to column: origin

□ Use Weight: year ☑ Use weight as attribute?

Available columns:

mpg
cylinders
cubicinches
horsepower
weightlbs
time to sixty

Important columns/Cumulative purity

Given zero or more columns held fixed on the right...

◆ ...find: 3 additional important columns

◇ ...compute improved purity for left columns, cumulative purity for right columns

Output from importance calculation:

**Figure 17-2** Advanced Mode of Column Importance

Advanced mode can work two different ways: finding several new important attributes or ranking available attributes.

- Finding Several Important Attributes

  To enter this submode, click the first of the two radio buttons in the middle of the dialog (*...find [number] additional important attributes*). If you click *Go!* with no further changes, the effect is the same as if you were in Simple mode, finding the specified number of important columns and automatically moving them to the right column. Near each column, the cumulative purity is given (that is, the purity of all the columns up to and including the one on the line.)

  Alternatively, by moving column names from the left list to the right list, you can prespecify columns that you want included and let the system add more. For example, to select the *cylinders* column and let the system find three more columns, click the *cylinders* column name, then click the right arrow between the lists.

  Clicking *Go!* lets you see the cumulative purity of each column, together with the previous ones in the list. A purity of 100 means that using the given columns, you can perfectly discriminate the different label values in the dataset.

- Ranking Available Attributes

  Advanced mode also lets you compute the change in purity that each column would add to all those that were already marked important, that is, they are in the list on the right. For example, you might move *cylinders* to the list on the right, and then ask the system to compute the incremental improvement in purity that each column remaining in the left column would yield. The cumulative purity is computed for columns on the right (already marked important).

  To enter this submode, click the second of the two radio buttons at the bottom of the dialog (*...compute improved purity for left columns, cumulative purity for right columns.*). This submode permits fine control over the process. If two columns are ranked very closely, you might prefer one over the other (for example, because it is cheaper to gather, more reliable, or easier to understand).

## Column Importance Notes

The importance of a column depends on the columns previously marked as important. For example, while *net-income* might be a good column individually, it might not be as important together with *salary* because they are likely to be highly correlated. The best set of three columns is not necessarily composed of the columns that rank highest individually. If two columns give the income in dollars and in another currency, they are ranked equally alone; however, once one of them is chosen, the other adds no discriminatory power to the set of best features.

Column selection is useful for finding the best three axes for Scatter Visualizer and Splat Visualizer. It is also useful for finding a good discriminatory hierarchy (hierarchy that separates different label values) for the Tree Visualizer when you select the label to be the key used in the Tree Visualizer.

All floating point values (**double**s or **float**s) are prediscretized using automatic discretization (see Chapter 3, "The Tool Manager"). If a column has no value given to it in the left list, the algorithm did not consider it; this is because it either had a single value (for example, when it is discretized into one interval), or the number of records that it would separate is not statistically significant.

## Column Importance and Relation to Classifiers

This section describes the differences among Column Importance, the importance ranking chosen by the Evidence Inducer, and the splits chosen by the Decision Tree Inducer. As Column Importance uses all of the data, these descriptions assume that you are running the inducers in "Classifier Only" mode, so that the inducers are using all of the data as well.

### The Discretization Process

The Column Importance algorithm and the Evidence Inducer discretize all continuous attributes using the automatic discretization algorithm (the same algorithm that is applied in automatic binning in the Tool Manager). The Decision Tree algorithm does not pre-discretize attributes (columns) and finds thresholds as the tree is built.

The main advantage of the automatic discretization is that it discretizes the continuous range into several intervals at once, while the Decision Tree makes only binary splits.

The main advantage of the Decision Tree algorithm is that it discretizes subsets of the data (those that reach a specific node where a test is done). Thus the discretization is "local" to those records as opposed to a "global" discretization.

## The Importance Function

The Evidence Inducer and Column Importance rank attributes based on "mutual information" as the purity measure. The Decision Tree Inducer, Option Tree Inducer, and Decision Table Inducer defaults to "normalized mutual information," which penalizes multi-way splits (see the description of splitting criterion in Chapter 11, "Inducing and Visualizing the Decision Tree Classifier"). Thus, the Decision Tree Inducer prefers an attribute with few values over attributes with many values. The default for Decision Trees can be changed to "mutual information."

## Dependence on Other Attributes

The Evidence Inducer ranks each attribute independently. If several attributes are highly correlated, they have similar ranking. If you use the Advanced mode from Column Importance, and the "...compute improved purity" option without any attributes chosen as important (that is, moved to the list on the right), the attribute ranking shown matches the sort order chosen by the Evidence Inducer.

The Column Importance tool, the Decision Tree Inducer, and the Decision Table Inducer all provide more powerful importance capabilities than the Evidence Inducer. All choose an importance ranking with respect to other columns.

In Column Importance, columns are judged as important relative to the set of columns in the list on the right. If two columns are highly correlated and one is chosen, the other will probably never be chosen; each column is chosen for its ability to provide more information about the label than is already present.

In the Decision Table Inducer, the Suggest button provides an importance facility similar to the column importance tool. Columns are judged as important relative to the set of columns already present in the mapping box. There are three major differences, however, between the Decision Table Inducer's suggest mode and the column importance tool. First, the Decision Table Inducer penalizes multi-way splits. Second, the Decision Table Inducer is capable of performing a more exhaustive search to find a better column ordering. Finally, the Decision Table Inducer does not report any purity scores—it merely ranks the columns.

The Decision Tree Inducer provides a more flexible importance ranking because different columns can be selected at different subtrees. For example, one column can be chosen for the left child of the root and another for the right child of the root. While this is appropriate for a Decision Tree, it is inappropriate for choosing a small set of columns to show in the Scatter Visualizer or Splat Visualizer. For these cases, the Column Importance tool is superior because it builds an "oblivious" Decision Tree in which every level of the tree tests the same column across the nodes. With Column Importance, a single column must be chosen for all combinations of the previously chosen columns.

## Sample File

The following example shows a case in which Column Importance might be useful. This example is associated with a sample dataset provided with MineSet. It shows how to work with the Column Importance mining tool, and explains the different outcomes and options.

When customers change their phone carrier from one telecommunications company to another, this is termed "churning." This is a common problem in the telecommunications industry. The data used to generate this example is in */usr/lib/MineSet/data/churn.schema.* The Column Importance mining tool lets you look at properties of this file.

Running the simple Column Importance mode yields the following three attributes:

- Total Day Charge.
- Number of customer service calls.
- State.

By running "compute improved purity" from the advanced mode, you can see that Total Day Charge and Total Day Minutes have the same purity ranking (48.67). By moving one of them to the right (for example, Total Day Minutes) and rerunning Compute Improved Purity, you can see that there is no value to the other (Total Day Charge). These two attributes are highly correlated.

Looking at the attributes when Total Day Minutes is on the right, we can see that the following are good:

- International plan (4.1)
- Number of Customer Service Calls (8.1).
- State (4.7)

You can choose to move International Plan to the right, because this information is readily available and easy to measure.

The other two attributes (Number of Customer Service Calls and State) remain highly important (in fact, their importance increases), so they are apparently not correlated with the International Plan.

By looking at the importance of attributes this way, you can determine which ones can be substituted with others that are equally good (or almost as good), but are easier to measure or understand. By looking at the purity, you can determine how much the additional attributes help. For example, in the above scenario, state significantly improves the purity. In the *iris* dataset, the third attribute chosen (*sepal length*) raises the purity only slightly higher. In some cases, the simpler, two-dimensional scatterplot might be easier to understand.

*Chapter 18*

# Selection and Drill-Through

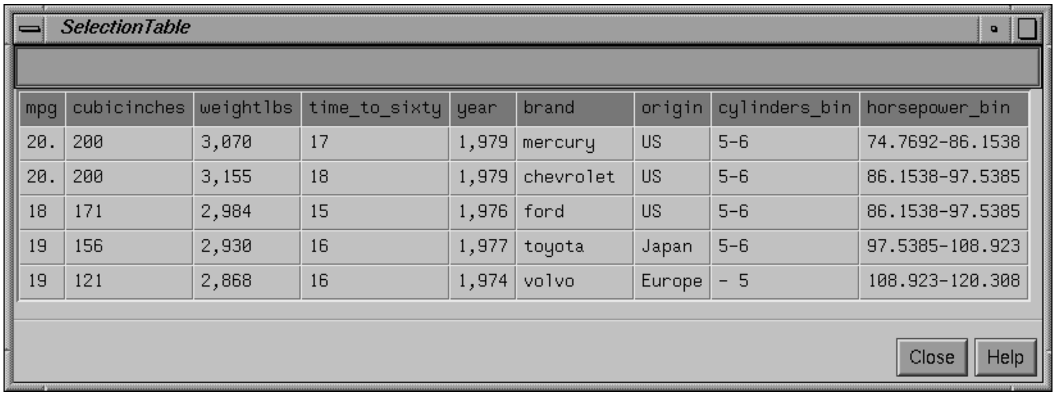
This chapter provides an introduction to selection and drill-through. With these features, you can select graphical objects in the visual tools, show the data associated with that tool, and send your selection to the Tool Manager to view the original data or to analyze it using another tool.

These features are common to all tools in MineSet, although certain tools have additional behavioral characteristics. Tool-specific details are provided at the end of this chapter.

## Multiple Selection

In most of the tools, selection is done using *Shift-Mouse 1*. Clicking mouse button 1 on an object without pressing Shift, selects the object under the cursor while deselecting all other previously selected objects. Holding down Shift while clicking mouse button 1 toggles the selection of that object without affecting any other selections. (Note that the Splat Visualizer has a different interface, described at the end of this chapter.)

When you select an item, a message describing that item appears in the tool's main window; by default, the visual tools only show information on the last object selected. A separate Record Viewer window displays a table, which shows the values for all selections. In the Tree and Map Visualizers, choose the Selection > Show Values to see this. Figure 18-1 shows an example of the selected values in the Record Viewer. See also “The Record Viewer” in Chapter 3.



| mpg | cubicinches | weightlbs | time_to_sixty | year | brand | origin | cylinders_bin | horsepower_bin |
|---|---|---|---|---|---|---|---|---|
| 20. | 200 | 3,070 | 17 | 1,979 | mercury | US | 5-6 | 74.7692-86.1538 |
| 20. | 200 | 3,155 | 18 | 1,979 | chevrolet | US | 5-6 | 86.1538-97.5385 |
| 18 | 171 | 2,984 | 15 | 1,976 | ford | US | 5-6 | 86.1538-97.5385 |
| 19 | 156 | 2,930 | 16 | 1,977 | toyota | Japan | 5-6 | 97.5385-108.923 |
| 19 | 121 | 2,868 | 16 | 1,974 | volvo | Europe | - 5 | 108.923-120.308 |

**Figure 18-1** Table of Values for Selected Objects

If a message has been set for the particular tool, that message also appears in the table. Columns in this table can be resized by dragging the separators between the columns. You also can click on a value to display the complete text of that value at the top of the table.

## Drill-Through

It is often useful to see or manipulate the original data from the data source that resulted in the current selections. This is referred to as *drill-through*. There are two entries on the Selections menu that perform drill-through:

- *Send to Tool Manager* — When this is selected, the history of operations that produced the visualization is placed in the Tool Manager. A filter operation corresponding to the user's selection in the visual tool is added to the history. The filter is placed as early in the history as possible, given the restrictions described below.
- *Show Original Data* — As with *Send to Tool Manager*, this option starts with the history of operations used to produce the visualization, and adds a filter operation as early as possible in the history. All non-filter operations coming after the filter in the history are removed. This new history is used to produce a table shown in the Record Viewer. If the filter can be placed at the beginning of the history, the data shown are the original records; otherwise, a warning is issued, indicating that the data are not totally original. The state of the Tool Manager is not altered (unless it is currently not running).

In either case, the Tool Manager performs the operation. If the Tool Manager is not running, it is started automatically.

Only visualizations generated using the Tool Manager can be used for drill-through. Each *.schema* file for these visualizations includes a *history* section that informs the Tool Manager how that file was generated. A few special-purpose mining visualizations such as Learning Curves, Confusion Matrices, Lift Curves, and the Rules Visualizer do not include a history and do not support drill-through.

When you select objects for drill-through, you are implicitly specifying a filter statement based on the visualized table. If the table was transformed before visualization, the Tool Manager might have to change the filter to place it earlier in the history. For example, if the filter is based on a binned column, the Tool Manager must change it so it refers to the pre-binned column.

The filter cannot always be placed at the beginning of the history because the Tool Manager cannot adjust the filter for all operations. Specifically, if the filter refers to any column created via *Add Column*, *Aggregate*, or *Apply Model*, the filter cannot be placed earlier in the history than the operation that created the column. Furthermore, the Tool Manager can never move a filter earlier than an existing Sample operation, since that would dramatically change the output of the sampling.

The Show Original Data mode tries to truncate the history to show the records from as early a stage as possible. To prevent this mode from showing more records than were selected, however, the truncation does not remove any other existing filter operations (either user-created or the result of previous drill-through).

## Tree Visualizer Specific Details

The Tree Visualizer selects drill-through criteria based on the location in the hierarchy and, if appropriate, the bar selected on that node. For example, in a sales hierarchy with region, city, and store, and with bars representing products, selecting the furniture bar for a particular city can generate a drill-through request selecting everything for which region=Western and city=Mountain View and product=furniture.

In the Decision Tree, the drill-through request is based on the decision criteria. For example, for an automobile decision tree, a drill-through request might be: "cubicinches <= 170 and mpg>20 and origin=US." In both cases, selecting the top node of the tree generates a drill-through of the entire dataset. For both Decision Trees and normal hierarchies, selecting the top node of the tree generates a drill-through of the entire dataset.

## Map Visualizer Specific Details

Drill-through in the Map Visualizer is based on the regions selected.

## Scatter Visualizer Specific Details

The Scatter Visualizer uses a selection box in addition to Shift-select. From the Selection menu select *Create Box Selection*. The box has tabs that can be used to resize or move it. You can not create more than one box.

The Scatter Visualizer does not have a key with which to select columns used for drill-through. The default is to use all non-array columns that have been mapped to graphical requirements (such as axes, size, color and sliders). From the Selections pull-down menu, the *Preferences* panel lets you select an alternate list of columns to be used in the drill-through.

A Record Viewer appears whenever a selection has been made. It shows the current selections. If the Record Viewer is closed, the selections are cleared.

## Splat Visualizer Specific Details

The Splat Visualizer uses a Selection box rather than Shift-click to select multiple objects. From the Selection menu select Create Box Selection. The box has tabs that can be used to resize it, or it can be moved. You can create more than one box.

The Record Viewer is tied to the Selection box; when the Record Viewer is dismissed, the selections are cleared. Drill-through is based on where the box is within the axes, and, optionally, on the sliders, if the *Use Slider on Drill Thru* item on the Selection menu is checked.

## Rules Visualizer Specific Details

Selection and drill-through are not implemented in the Rules Visualizer.

*Chapter 19*

# File Exchange Between MineSet and SAS

This chapter describes the support for file exchanges between MineSet and SAS.

## Overview

Exchanging data sets between MineSet and SAS is done through two utilities: *mineset2sas* and *sas2mineset*. To convert a MineSet *.schema* and *.data* file pair into a SAS data set, use *mineset2sas*. To convert a SAS data set into MineSet *.schema* and *.data* files, use *sas2mineset*. Both *mineset2sas* and *sas2mineset* invoke the SAS executable; thus, SAS must be installed on the machine on which these conversion utilities are used.

## Converting MineSet Data Files to SAS Data Sets

Use *mineset2sas* to convert MineSet data files into SAS data sets. The syntax for this is

```
mineset2sas <MineSet file> <SAS libref.datafile> [options]
```

Options are

- **-svsc** to save the script sent to SAS. The script normally is deleted after use.
- **-names** <*namefile*> to save trimmed column names in <*namefile*>. The script normally is deleted after use.

For example:

```
mineset2sas cars sasuser.cars -svsc -names cars.names
```

*mineset2sas* converts the MineSet *.schema* and *.data* files (in this case, *cars.schema* and *cars.data*) into a SAS data file. Currently, only string and numeric data types are supported. The MineSet *.data* file must be in ASCII format; binary format is not supported. To save MineSet data files in ASCII, deselect Use binary data files in Tool Manager Preferences.

SAS column names (or, in SAS terminology, variable names) can consist of only letters, and underscore characters. The first character in a column name cannot be a number. Furthermore, SAS column names can be up to eight characters long. Since any character string can be a legal MineSet column name, *mineset2sas* maps MineSet column names to legal SAS column names. The rules for this mapping are:

- Any invalid character is replaced with an underscore.
- If the first character is a digit, an underscore is prepended to the column name.
- Column names are truncated to eight characters. If this truncation results in non-unique column names, the ends of the conflicting column names are replaced with sequential numbers, thus creating unique column names.

To preserve as much of the full column names as possible, *mineset2sas* also saves the first 40 characters of each column name as the column label.

## The -names *namefile* Command Line Option

To get a listing of the column names before and after conversion into SAS format, specify the **-names** <*namefile*> command line option. When *mineset2sas* executes, it writes out a mapping of the column name changes to the specified file. For example:

```
`date of birth` -> `date_of_`
`92census` -> `_92censu`
`# of days to end of quarter` -> `__of_da0`
`# of days to end of year` -> `__of_da1`
`# of davenports` -> `__of_da2`
```

## The -svsc Option

The *mineset2sas* utility reads the schema for the specified data file, and writes a customized SAS script. SAS, which must be installed in */usr/sbin/sas*, is invoked with this script to read and convert the data. The script sent to SAS is normally deleted after use. With the **-svsc** option, the script is saved as the file *mineset2sas.sas*. If there is an error in the script processing, the SAS error log is saved as *mineset2sas.log*.

## Converting SAS Data Sets Into MineSet Data Files

Use *sas2mineset* to convert SAS data sets into MineSet data files. The syntax for this is

```
sas2mineset <SAS libref.datafile> <MineSet file> [options]
```

Options are

- `-nodata` creates only a *.schema* file, no *.data* file.
- `-svsc` saves the scripts sent to SAS.
- `-nolabel` indicates that you do not want labels used for column names.
- `-names` <*namefile*> restores long column names from <*namefile*>, created by *mineset2sas*.

For example,

```
sas2mineset sasuser.houses -svsc -names houses.names
```

The *sas2mineset* utility converts a SAS data file into MineSet *.schema* and *.data* files. Currently, this utility supports only string, numeric, and date data types.

### The -nolabel Option

SAS only supports eight-character long column names, but allows optional 40 character labels for each column. MineSet sets no limit on the column name length, so, by default, *sas2mineset* uses the column labels to name the columns in the output file, if labels have been defined. To force *sas2mineset* to use the SAS column name for each column, even if a label is specified, add the **-nolabel** option to the command line.

### The -names *namefile* Option

If a MineSet data file is converted into SAS with *mineset2sas* and then back to MineSet format with *sas2mineset*, a column name map file can be created to keep track of the original column names. To have *sas2mineset* use a name map file created by *mineset2sas*, add the **-names** <*namefile*> option to the command line, and specify the same map file as specified when the file was converted into SAS format with *mineset2sas*. This option is useful only for data files with column names longer than 40 characters, since *mineset2sas* saves up to 40 characters in the column label.

Note that the **-name** <*namefile*> option overrides the **-nolabel** option.

## The -nodata Option

To create just a MineSet schema file without downloading the data from a SAS data file, add the `-nodata` option to the command line.

## The -svsc Option

The *sas2mineset* utility writes two customized SAS scripts to retrieve the specified data file. The first script extracts column descriptions; the second extracts the data. The scripts are normally deleted after use. With the **-svsc** option, the scripts are saved as *getschema.sas* and *getdata.sas*, respectively. If there is an error in the script processing, the SAS error logs are saved as *getschema.log* and *getdata.log*, respectively.

*Chapter 20*

# MineSet Web Extensions

This chapter describes the MineSet extensions that are provided to let you create or view visualizations and/or interact with MineSet over the web.

## Overview

MineSet Web extension allows visualizing files and data generated by MineSet software over the Web. This can be done in two ways.

- MineSet mtr extension
  MineSet mtr extension lets you place MineSet configuration, schema and data files into an archive file, which can be embedded in a web page as an html tag. Once the user clicks on the hyperlink in Netscape, the browser automatically invokes the mineset_weblaunch program. This brings up the MineSet visual tool. The machine that the browser is running on must have the MineSet client software installed.
- MineSet Remote View
  MineSet Remote View extension allows machines that do not have MineSet software installed to view visualizations through the Web. This is done via two cgi scripts that are included with the MineSet software distribution. The cgi scripts must be configured properly and installed in the Web Server machine. The cgi script *rview_file.cgi* must get called from a *.html* file with a MineSet visual tool file as an argument. The cgi script *rview_dir.cgi* provides the client (user who accesses the script) with a list of available visualizations. The user then can select any file via multiple popup menus and click on the invoke button to launch the MineSet tool.

## MineSet Web Extension Files

All MineSet Web Extension files are located in the */usr/lib/MineSet/www* directory, which contains three subdirectories.

### scripts Subdirectory

| Script | Purpose |
|---|---|
| *mineset_webinstall_server* | This program configures the httpd server. Use it to configure the server and the MineSet Remote View Program. If the web server is a remote machine, copy this file along with *mineset_wsf.tar* to the remote machine. |
| *mineset_webinstall_client* | This program configures the Web browser (Netscape). Use it to configure the client. |
| *mineset_weblaunch* | This program is invoked by the web browser (Netscape). It un-archives the *mtr* file and brings up the appropriate viewer. |
| *mineset_makemtr* | This program creates one or more *mtr* files from files created either by Tool Manager or created manually. The *mtr* file is sent over the network and is used by mineset_weblaunch to invoke MineSet visual tools. |
| *mineset_wsf.tar* | This is a tar file of various files needed by mineset_webinstall_server. If the web server is a remote machine, copy this file along with mineset_webinstall_server to the remote machine. |

### examples Subdirectory

| File | Purpose |
|---|---|
| *index.html* | This file provides an index of all the mtr files supplied with MineSet. |
| *rview_file.html* | This file illustrates how you should embed hyperlinks to invoke *mineset_rview* on files and directories. |
| *adult-salary.eviviz.mtr* | mtr file of */usr/lib/MineSet/eviviz/examples/adult-salary.eviviz.* |
| *nl.births.mapviz.mtr* | mtr file of */usr/lib/MineSet/mapviz/examples/nl.births.mapviz.* |
| *company.scatterviz.mtr* | mtr file of */usr/lib/MineSet/scatterviz/examples/company.scatterviz.* |
| *cars-dt.treeviz.mtr* | mtr file of */usr/lib/MineSet/treeviz/examples/cars-dt.treeviz.* |
| *cars-odt.treeviz.mtr* | mtr file of */usr/lib/MineSet/treeviz/examples/cars-odt.treeviz.* |
| *churn-dt.treeviz.mtr* | mtr file of */usr/lib/MineSet/treeviz/examples/churn-dt.treeviz.* |

### examples/rview_dir Subdirectory

| File | Purpose |
|---|---|
| **.treeviz.** | Treeviz configuration and data files to be dynamically indexed by *rview_dir.cgi.* |
| **.mapviz.** | Mapviz configuration and data files to be dynamically indexed by *rview_dir.cgi.* |
| **.eviviz.** | Eviviz configuration and data files to be dynamically indexed by *rview_dir.cgi.* |
| **.scatterviz.** | Scatterviz configuration and data files to be dynamically indexed by *rview_dir.cgi.* |
| **.ruleviz.** | Ruleviz configuration and data files to be dynamically indexed by *rview_dir.cgi.* |
| **.dtableviz.** | Decision Table configuration and data files to be dynamically indexed by *rview_dir.cgi.* |
| **.clusterviz.** | Clusterviz configuration and data files to be dynamically indexed by *rview_dir.cgi.* |

## MineSet Web Installation (Client)

During the MineSet client installation the client part of the web extension is automatically installed under most circumstances. To see whether it was automatically installed run the following command.

```
sh -c "grep mineset /usr/local/lib/netscape/mime.types > /dev/null ;
echo $?"
```

If the output is 0 then you don't need to do the client installation. If the output is not 0 then you need to install the MineSet web-client extension. A program is provided for the MineSet Web installation. Before you start the installation you must make sure that MineSet Client is installed in the machine you're trying to configure. If it is not installed please install the MineSet software before you try to configure the MineSet Web Extension.

To configure the client, run the following command.

```
cd /usr/lib/MineSet/www/scripts ; ./mineset_webinstall_client
```

The program prompts you for the location of the files *mailcap* and *mime.types*. After you provide the correct names, the program adds the corresponding entries to the files.

## MineSet Web Installation (Server)

A program is provided for the MineSet Web installation. Before you start the installation you must make sure the following software, listed below is installed. If you are not familiar with the details contact your system administrator or webmaster and request that the installation be done for you.

For MineSet Web installation to work properly, you need

- a Netscape browser
- an httpd server

### Setting Up the Server

The server can be running on either the local machine or a remote machine. You must know:

- the name of the machine on which your httpd server runs, and
- the directory where the publicly accessible *.html* files are stored

Typically the files are located under */var/www/htdocs*. The machine name is included between *http://* and the first /. If you are accessing files by using *http://some-machine.xxx.com/file.html*, then *some-machine* is the name of the machine, and *xxx.com* is the domain name. An httpd daemon must be installed and running on *some-machine*.

You also must know where the httpd configuration files are stored in the server. If you are running the Netscape fast-track server, the configuration files usually are in */usr/ns-home/httpd-machine/config*, where *machine* is the name of your machine. If you are running a version of ncsa-httpd or apache, the files might be located in */usr/local/etc/httpd/conf* or */var/www/server/conf*. If you are not sure where the config files are located, contact your system administrator or webmaster.

Once you know where your Server configuration files are located, you need the following two files to perform the installation

- *mineset_webinstall_server*
- *mineset_wsf.tar*

## Local Installation

A script is provided with MineSet that helps with the MineSet installation. Since configuration of Web Servers varies from machine to machine, the program prompts you for the location of files. It tries to make a reasonable guess and provides defaults; however, it is better if you know where the files are located before you supply them to the program.

### Configuring MineSet Web Extensions for the Local Server

To start the installation, enter the following

```
cd /usr/lib/MineSet/www/scripts
./mineset_webinstall_server -s
```

You are prompted for the location of your server mime.types file. Once you give the correct file name, it adds an entry and tries to restart the httpd daemon. If it can not restart your daemon, you must do it manually. If you're not sure about how to restart the httpd daemon, ask your system administrator or webmaster.

### Configuring MineSet Web Extensions for a Remote Server

First copy over the following two files to the server

- *mineset_webinstall_server*
- *mineset_wsf.tar*

Once you're copied them over, cd to the directory where you copied the files. Then start the installation by entering

```
./mineset_webinstall_server -s
```

It prompts you for the location of your server *mime.types* file. Once you give the correct file name, it adds an entry and tries to restart the httpd daemon. If it can not restart your daemon, you must do it manually. If you're not sure about how to restart the httpd daemon, ask your system administrator or webmaster.

## MineSet *mtr* Files

For MineSet mtr extension to work, you must have MineSet software installed in your machine or the machine where the Netscape browser is installed. MineSet *mtr* files are archives of MineSet files generated by the Tool Manager or created manually. Creating an *mtr* file is very easy. Once created, it can be used as a hyperlink in an html page. The *mtr* files are very effective in sharing multiple visualizations over the web, eliminating the need for attaching huge files in mails, remote copies, or file transfers (ftp).

Since *mtr* files are in a compressed format and use the underlying http protocol, the transfer of an *mtr* file is very fast and does not require a cumbersome setup on the part of administrators.

### Creating *mtr* Files

An *mtr* file can be created in the following ways.

1. From Files created by Tool Manager

   Once you have launched a tool from the Tool Manager, go to the directory from where you launched the Tool Manager and invoke *mineset_makemtr* using the name of the file(s) as the arguments. For example, if you have launched the Tree Visualizer and the Rule Visualizer from Tool Manager, then to create *mtr* files use the following command.

   ```
   % mineset_makemtr foo.treeviz foo.ruleviz
   ```

   This creates two files called *foo.treeviz.mtr* and *foo.ruleviz.mtr*.

2. Mapviz files with *.gfx* extensions

   If you have generated a Mapviz visualization that uses the *.gfx* extension, you must use the **-f** option of *mineset_makemtr*, and mention all the files that you want to include in the archive. For example, you can use the following command

   ```
   % mineset_makemtr -f sales.mapviz sales.mapviz.schema
   sales.mapviz.data sales.hierarchy sales.gfx
   ```

3. From Files not created by Tool Manager

   If you've created some files without using Tool Manager, you still can create a *mtr* file from those files. You must use the -l option of mineset_makemtr. Suppose you want to create a mtr file from the MineSet scatterviz example directory, use the following command.

   ```
   % mineset_makemtr   -l
   /usr/lib/Mineset/scatterviz/examples/company.scatterviz
   ```

4. Creating an *mtr* file from given files

   Under certain circumstances, you might want to generate an *mtr* file while bypassing the checks performed by mineset_makemtr. If the checks are not performed, you are not guaranteed that the *mtr* file will work. You must check its usability by launching it from the web. You also must use the -f option of mineset_makemtr. Suppose you want to create an *mtr* file from the following files: *foo.treeviz*, *foo.treeviz.schema*, and *foo.treeviz.data*, then use the following command.

   ```
   % mineset_makemtr   -f   foo.treeviz   foo.treeviz.schema
   foo.treeviz.data
   ```

   Unlike the other options, this one can create only one *mtr* file.

5. Creating a hyperlink to the *mtr* file

   After the *mtr* file is created, it should be moved to the directory containing all your *.html* files. For Netscape to launch an *mtr* file, you can invoke it directly by entering

   ```
   http://yourserver/directory/foo.treeviz.mtr
   ```

   in the Netscape Location window; or you can make a link to it from a page by adding the following line in the *.html* file for that page.

   ```
   <A HREF="foo.treeviz.mtr">foo.treeviz.mtr </A>
   ```

After you launch a visualization via the Web browser from an *mtr* file, a temporary directory is created to store the files. These files are deleted after the visualization tools are launched. If you want to save these files, set the environment variable *MINESET_MTR_FILE_SAVE* to *TRUE*; *mineset_weblaunch* then prompts you if want to save or delete the file. If you click *Save*, the files are saved; otherwise, they are deleted.

## MineSet Remote View

MineSet remote view lets you view MineSet visual tools over the web on any UNIX platform and on PCs. The X Server running on the UNIX machine must be OpenGL-enabled. The PCs must be running an OpenGL-enabled X server, such as HummingBird Exceed 3D. You also should have:

- Perl version 5.002 or greater installed on your (server) machine
- the CGI.pm module version 2.35 or greater. The CGI.pm module is included with the MineSet distribution and is installed in the proper place during Remote View Installation.

### Installing MineSet Remote View

First you must copy over *mineset_webinstall_server* and *mineset_wsf.tar* to the machine on which you are going to install Remote view. To do this, enter

```
% cd /usr/lib/MineSet/www/scripts
% ./mineset_webinstall_server -r
```

You are prompted for the location of your Perl binary, the Perl library and your Perl version. It provides reasonable defaults. If the default is correct, you can hit *Enter* to install MineSet Remoteview in the proper place. If you are not sure about some of the answers, ask your system administrator or webmaster.

### Configuring and Using *rview_dir.cgi*

The *rview_dir.cgi* program that is supplied with the MineSet distribution is generic and must be configured properly. By default, it works only for example files installed under */usr/lib/MineSet/www/examples*. Here are the steps you must follow to configure *rview_dir.cgi*.

1. Rename the rview_dir.cgi program

   Copy the program and rename it with a unique suffix, such as *rview_<login>.cgi* where *<login>* is your login name. Since *rview_<login>.cgi* indexes one directory at a time, you must have multiple copies of the script with the $DIR entry set to a particular directory to have multiple directories indexed. To set the $DIR entry properly, edit the *rview_<login>.cgi* program, and look for the following line

   ```
   ############# EDIT THE LINE BELOW ################
   $DIR="/usr/lib/MineSet/www/rview_dir"
   ##################################################
   ```

   Replace */usr/lib/MineSet* with the full pathname of the directory that will contain your visualization files. This directory must be available and readable by the user id (*uid*) under which the httpd daemon is running. Suppose your files reside in */usr/people/jdoe/mineset_files*, then the $DIR entry in rview_jdoe looks like

   ```
   ############# EDIT THE LINE BELOW ################
   $DIR="/usr/people/jdoe/mineset_files"
   ##################################################
   ```

   There are several other options that you can set in both *rview_dir.cgi* and in *rview_file.cgi*.

| Variable | Purpose |
|---|---|
| $BODY_FILE | Default is */usr/lib/MineSet/www/examples/rview_file_body.txt*. This file contains the text that will be displayed when the cgi script is invoked. This file can contain embedded html tags. |
| $PR_KILL | Default is OFF<br>This variable specifies whether a visual tool invoked by the user will get killed after a certain period of time. This is a useful feature to avoid overloading the server. To turn this feature on, set $PR_KILL="ON". |
| $TIMEOUT | Default is 10 minutes<br>If $PR_KILL is "ON" then the processes will get killed after this number of minutes. |

| Variable | Purpose |
|---|---|
| $LOGGING | Default is ON<br>This variable, if set to "ON, " provide detailed logging information. The information is in the following format.<br>display user time program filename<br>where<br>display = name of the display the user entered<br>user = name of the user if available<br>time = time the program was launched<br>program = name of the launched visual tool<br>filename = name of the file that was viewed |
| $LOGFILE | Default is */usr/tmp/rview-log*<br>If $LOGGING is ON then the logfile where the entries will get recorded is specified in $LOGFILE. The log file should reside in a secure place. The file must be writable by the userid under which the cgi scripts are run. This is generally *nobody*. |
| *$THIS_URL* | Default is *http://localhost/cgi-bin/rview_dir.cgi*<br>This entry should be set to the full URL entry an user uses to access the script. |
| *$RESTRICT* | Default is OFF<br>This is available only in *rview_file.cgi*. If it is on, files only in the directory $RESTRICT_DIR are shared. If `$RESTRICT` is set to `ON` and `$RESTRICT_DIR="public_html`, then files residing in *public_html* for any user can be accessed over the web. This is for security reason; you can turn it off if you are sure there are no confidential files in your directory. |
| *$RESTRICT_DIR* | Default is public_html<br>This entry should be set to a directory name where users store their*.html* files. |

2. Invoke *rview_dir.cgi*

   *rview_dir.cgi* is invoked in the following way

   **`http://yourserver/cgi-bin/rview_dir.cgi`**

   When invoked, *rview_dir* reads the text from the file specified in *$BODY_FILE*; it then creates a web page with popup menus and an *Invoke* button for each of the visual tools. A user can choose any file. Clicking on the *Invoke Viztool* button invokes the selected visual tool.

## Configuring and Using *rview_file.cgi*

The *rview_file.cgi* takes a file name as an argument so once the script is installed properly in cgi-bin it can handle any request. The user does not need to change the script, only enter the location of the file in a *.html* file. All the variables (listed above) that are set in *rview_dir.cgi* are supported in *rview_file.cgi*. A single file can embed links to multiple visualizations via different submit buttons. A sample file, *rview_file.html,* is included with the distribution. It is located in the */usr/lib/MineSet/www/examples* directory. For each visual file you embed, there must be two entries. If you want the user to see the visualization generated by the Scatter Visualizer on the *iris* dataset, add the following lines to a *.html* file

```
<INPUT NAME="View Scatterviz" TYPE="hidden"
VALUE="/usr/lib/MineSet/examples/iris.scatterviz">
Clicking on the following button will bring up a view of the iris
dataset. The tool that will be launched is scatterviz.
<INPUT TYPE="submit" NAME="button" value="View Scatterviz">
```

For the script to work properly, the quoted string after the NAME= entry on the first line must be exactly equal to the quoted string after the `value=` entry on the last line. For example, the entry `View Scatterviz` appears both after the `<INPUT NAME=` entry in the first line, and `<INPUT TYPE="submit" NAME="button value="` in the fourth line.

Also ensure that

- the following line appears in the *.html* file

  ```
  <form method=post action="/cgi-bin/rview_file.cgi">
  ```

- you have a text box to which the user can set the DISPLAY. For example

  ```
  DISPLAY  <INPUT TYPE="TEXT" NAME="DISPLAY" SIZE=30>
  ```

- you add a line asking the user to give the program access to the Xserver. You can put the following lines in your html page

  ```
  Since the visual tools will run on this server, you need to grant
  us access to your DISPLAY. You can do this easily by executing the
  command <b>xhost + machine</b>
  ```

  Replace "machine" with the name of the machine on which the cgi script resides.

The easiest way to create a customized *.html* file that includes all of the above is to copy *rview_file.html* and edit it as necessary.

## MineSet Web Extension Security-Related Issues

It is very important to understand the security implications before installing MineSet Web Extensions. The following security concerns should be addressed before you install the web extensions.

- MineSet *mtr* file extensions

  When you publish an *mtr* file, the files that are included in it are sent to the client and can be saved by the user.

- For *rview_login* to work, you (the client) must use the command **`xhost + machine`**. This allows the server to use your X display and compromises security. This is a limitation of the X protocol and not of MineSet Web Extensions. If you enter the command xhost + machine to invoke a visual tool, then xhost - machine as soon as you quit the MineSet visual tool.

- Most MineSet visualization tools support an `-execute` option in the configuration files. Double-clicking on an object executes the command listed in the `-execute` option. This can be used maliciously to embed arbitrary commands in the configuration file, which then are triggered when a user double-clicks on an object. To prevent this, a warning message appears, asking whether the user really wants to execute this command. This feature can be turned off by setting the environment variable *MINESET_IGNORE_WARN_EXECUTE* to *TRUE*. Set this variable only if you're going to launch *mtr* files from trusted machines.

*Appendix A*

# Flat File Support for MineSet

This appendix describes the *.schema* and the *.data* files that are required to define the MineSet flat files. The Tool Manager also generates *.schema* files to include the *.schema* files for Tree Visualizer, Map Visualizer, Scatter Visualizer, and Splat Visualizer.

This appendix first discusses the*. data* file (the data file), then the *.schema* file; the final section notes the exceptions to the descriptions for these files for some tools.

## The Data File

In its simplest form, the data file consists of a list of lines, each containing a set of fields, each separated by one tab. (Other separators are also allowed—see "Input Options" on page 529—but only one, per file, may can separate each field). All lines must contain the same fields. (The interpretation of the fields is specified by the *.schema* file, described in the next section.) For example, the first few lines of retail store data might look like this:

```
Eastern  Maryland  Baltimore  1816  appliances  72  115  138
Eastern  Maryland  Baltimore  1816  clothing  355  344  395
Eastern  Maryland  Baltimore  1816  electronics  156  182  209
Eastern  Maryland  Baltimore  1816  furniture  78  75  82
Eastern  Massachusetts  Boston  1331  appliances  48  68  81
Eastern  Massachusetts  Boston  1331  clothing  307  258  296
Eastern  Massachusetts  Boston  1331  electronics  38  183  210
Eastern  Massachusetts  Boston  1331  furniture  52  69  75
Eastern  Massachusetts  Boston  1220  appliances  37  63  75
Eastern  Massachusetts  Boston  1220  clothing  233  240  276
Eastern  Massachusetts  Boston  1220  electronics  175  208  239
Eastern  Massachusetts  Boston  1220  furniture  35  53  58
```

In this example, the first five columns are strings: region, state, city, store ID, and product. These are followed by three numbers, representing current sales, last year's sales, and the sales target.

The data file cannot contain blank lines or comments. Missing or extra data on a line causes an error.

**Note:** One tab (the default separator) separates each field. Do not insert multiple tabs to line up the fields visually; doing so generates blank fields. It is possible to use other characters, such as a colon (:), as a separator. In this case, the first line appears as:

```
Eastern:Maryland:Baltimore:1816:appliances:72:115:138
```

The order of the columns must match the format of the *.schema* file. For some visual tools, the order of the rows can affect the layout of the final graphic. See the tool-specific appendices for details.

Any field in the data can also be a "?", indicating that the data is null (unknown). See Appendix J, "Nulls in MineSet."

**Note:** MineSet also supports a binary format, which currently is not documented.

## Data Types

MineSet supports integer, floating-point number, and string data types, as well as arrays of these types. The following data types are supported:

- **int** represents a 32-bit signed integer.
- **float** represents a single-precision floating point number. The decimal point is optional. Numbers in exponential "e" notation are also accepted.
- **double** represents a double-precision floating point number. The decimal point is optional when representing a floating point number. Numbers in exponential "e" notation are also accepted. The superior precision of **double** can be useful for accurately representing large numbers, since **float** can represent only seven or eight significant digits accurately. This superior accuracy, however, consumes twice the memory space of **float**.

- **dataString** represents a string that is unlikely to appear multiple times. If it appears multiple times, several copies are made. A **dataString** can be used to store a memory address. Addresses are unlikely to be compared, and each record can have a different address.
- **string** represents a string of characters that can appear multiple times in the data file. Unlike a **dataString**, only a single copy of a given string is stored in memory, no matter how many times it appears in the data. This saves memory for strings appearing many times.

  Comparing **strings** is also much quicker than comparing **dataString**s. Reading in **strings** can be slower than reading in **dataStrings** because it is necessary to look for duplications. An example of **string** use is a division name that appears once for each department in the division. If you are unsure whether to use a **string** or a **dataString**, use a **string**.
- **fixed string** represents a string of fixed length. Like a **dataString**, if a **fixed string** appears multiple times, multiple copies are made. In general, **fixed strings** are used internally for representations of data from data bases, and are generally better to use than **strings** or **dataStrings**.
- **date** represents a date and time. In the data file, a **date** appears with the format MM/DD/YYYY HH:MM:SS. Output from MineSet always represents dates with four-digit years, although two-digit years are acceptable for input. MineSet follows the X-OPEN standard for interpreting two-digit years. Fields with values 69 or greater are considered to be from the 20th century (1969-1999), and values from 0 to 68 are considered to be from the 21st century (2000 - 2068).

## Arrays

In MineSet, you can use one-dimensional or two-dimensional arrays of fixed or variable size.

In a fixed-sized array, all entries of the given type have the same number of values. For example, the budgets of the 50 United States, can be represented by a separate float column for each state, or by a single array with 50 floats.

A special form of a fixed array is an “enumerated array.” Like the normal fixed array, there are a fixed number of values in the array; however, the values are associated with an enumeration. For each value in the enumeration, there is a single entry in the array.

For example, if there is an enumeration representing the 50 states, an enumerated array based on this enumeration has 50 values.

A variant of the "enumerated array" is the "null enumerated array," which has an additional entry at the beginning for null (represented as a "?" ). For example, with the enumeration of the 50 states, the null enumerated array has 51 values, one for NULL, and the remaining 50 for the 50 states. The null array element could be used for entries where the state is unknown.

The tree visualizer also supports variable length arrays (see Appendix B, "Creating Data and Configuration Files for the Tree Visualizer," for details).

As with the columns, arrays are represented as values separated by tabs or other separators. For a fixed-sized array, the same separator can be used for columns and for individual array elements (in which case, array elements are not visually distinguished from separate columns). You can also define a different separator. In the sales example (in "The Data File" on page 521), for example, you can treat the location as a four-element array, rather than as four columns. It then could be represented like this:

```
Eastern:Maryland:Baltimore:1816	appliances	72	115	138
```

Here, the array is separated by colons, and the columns are separated by tabs. (For clarity, the rest of this document uses tabs to separate columns, and colons to separate array elements.)

For a variable-length array, you must use different separators for the array and for the columns; otherwise, it is impossible to determine where the variable-length array ends and the other columns begin.

### Null Values

Any field or array element in the data file can also have the value "?" (question mark), indicating an unknown or null value (see the discussion of nulls in Appendix J).

## The *.schema* File

The schema file consists of an input section, which defines the name and format of the file. (The *.schema* files generated by the Tool Manager can also contain a history section, which is a copy of the *.mineset* file. This section is used by drill-through and would normally not be present in manually generated *.schema* files.)

A typical input section might look like this:

```
input {
   file "store";

   string region;
   string state;
   string city;
   string storeId;
   string product;
   float sales;
   float lastYear;
   float target;

   options separator ‘:’;
}
```

This example states that the input file is called *store*, and that there are eight fields: five of type **string**, three of type **float**.

### Variable Names

A variable name can appear in two formats:

- In the first format, it is a letter followed by a number of letters, digits, or underscores. It cannot be a keyword, and should not be quoted.
- In the alternate form, the variable name should be surrounded by back quotes (‘). In this form, the variable name can match a keyword, and can contain even non-alphanumeric characters. The primary purpose of this second form is for *.schema* files generated automatically by the Tool Manager.

There is no scoping of variable names; a given variable name can only be declared once in the *.schema* file.

## Strings and Characters

Strings and characters in the *.schema* file follow C-language conventions. Strings are in double quotation marks ("), and characters are in single quotation marks (′). All standard backslash conventions are followed (for example, \n represents a new line).

## Comments

Comments begin with a pound (#) symbol at the beginning of a line; anything after this symbol to the end of the line is ignored, up to the end of the line.

## File Statements

The file statement names the data file to be read. This statement is required. Its syntax is:

```
file "filename";
```

*Filename* must be in double quote marks. If it is a relative pathname (no leading slash), it is first sought in the directory containing the current *.schema* file. If it is not found in the current *.schema* file's directory, the file is sought in the current directory.

## Data Statements

The data statements declare the columns in the data file. The columns must be declared in the order they appear in the data file. The format of most data statements is

```
type name;
```

where *type* is **int**, **float**, **double string**, **dataString**, **date**, and **fixedString(n)**, where *n* is an integer representing the width of the string; *name* is the variable name. Unlike in C, only one variable can be declared per statement.

### Enumerations

The syntax for declaring an enumeration is:

```
enum type name { value, value...};
```

For example:

```
enum string state {
   "Alabama",
   "Alaska",
   ...
   “Wyoming"
};
```

The word “string” indicates that the enumeration maps integers to strings; they can also be mapped to other types.

Note that for compatibility with MineSet 1.0, “enum” can be replaced with “key.”

Once an enumeration is declared, a column can be declared to be of that enumeration using the following syntax:

```
enum enumname columnname;
```

For example:

```
enum state st;
```

declares `st` to be a variable of state enumeration. The input file corresponding to this column must contain values from 0-49 (or “?” representing null); however, the output shows the state name.

Enumerations also can be used to declare enumerated arrays (see “Enumerated Arrays”).

### Fixed Arrays

Arrays are also declared using data declarations. The simplest form is the fixed array. The declaration syntax is

```
type name [ number ] ;
```

For example:

```
float revenue [50];
```

You can also override the separator by declaring it as

```
type name [ number ] separator ‘char’;
```

For example:

```
float revenue [50] separator ‘:’;
```

If no separator is specified, the default column separator (usually a tab) is used.

### Enumerated Arrays

To declare an enumerated array, first declare the enumeration (see the “Enumerations” subsection on page 527). Then declare the array using the following syntax:

```
type name [ enum keyname ];
```

or

```
type name [enum keyname ] separator ‘char’;
```

For example:

```
float revenue [enum state];
```

As with the normal fixed array, you can also specify a separator. Note that for compatibility with MineSet 1.0, the word "enum" can be omitted from within the brackets. To declare a null enumerated array, use the syntax:

```
type name [ null enum keyname ];
```

or

```
type name [ null enum keyname ] separator `char';
```

For example:

```
float revenue [null enum state];
```

indicates that the array contains one additional value at the beginning, corresponding to null.

### Input Options

The input section of a data file has several options. All options statements begin with the word *options* and have one or more comma-separated options.

- The separator option defines the separator between columns in the data file. The default separator is a tab. The syntax is:

  ```
  options separator ‘char’;
  ```

  For example:

  ```
  options separator ‘:’;
  ```

  **Note:** Arrays can override the separator.

- The backslash option controls whether backslashes in the input data are treated specially or like other characters. The syntax is:

  ```
  options backslash off;
  options backslash on;
  ```

  The default is off. If backslash processing is on, separators in the input data preceded by backslashes are treated as regular characters rather than separators. Also, within strings, standard C-style backslash processing is done.

## Exceptions

The following exceptions apply to the *.schema* and *.data* files:

- The Tree Visualizer supports only one-dimensional arrays.
- The Tree Visualizer supports variable-length arrays.
- The Map Visualizer and the Scatter Visualizer support a special enum format for dates.
- The Tree Visualizer and the Map Visualizer support the Monitor option.

**Note:** These exceptions are discussed in detail in the respective tool’s appendix.

*Appendix B*

# Creating Data and Configuration Files for the Tree Visualizer

The first part of this appendix describes the types and formats of data supported by the Tree Visualizer. Data input to the Tree Visualizer must be provided as a single file containing raw data, usually in a tab-separated ASCII text form.

The second part discusses the configuration file, which describes how the Tree Visualizer reads in, and graphically displays, the data file.

Note that both the data and configuration files can be generated automatically by the Tool Manager (see Chapter 3).

**Note:** Read Chapter 5, "Using the Tree Visualizer," before using this appendix.

## The Data File

In its simplest form, the data file consists of a list of lines, each containing a set of fields, each separated by one tab. (Other separators are also allowed—see "Input Options" on page 544—but only one, per file, can separate each field). All lines must contain the same fields. (The interpretation of the fields is specified by the configuration file, described in the next section.) For example, using the retail store data (*store.treeviz* file) provided as part of the Tree Visualizer package, the first few lines of the input file look like this:

```
Eastern  Maryland  Baltimore  1816  appliances  72  115  138
Eastern  Maryland  Baltimore  1816  clothing  355  344  395
Eastern  Maryland  Baltimore  1816  electronics  156  182  209
Eastern  Maryland  Baltimore  1816  furniture  78  75  82
Eastern  Massachusetts  Boston  1331  appliances  48  68  81
Eastern  Massachusetts  Boston  1331  clothing  307  258  296
Eastern  Massachusetts  Boston  1331  electronics  38  183  210
Eastern  Massachusetts  Boston  1331  furniture  52  69  75
Eastern  Massachusetts  Boston  1220  appliances  37  63  75
Eastern  Massachusetts  Boston  1220  clothing  233  240  276
Eastern  Massachusetts  Boston  1220  electronics  175  208  239
Eastern  Massachusetts  Boston  1220  furniture  35  53  58
```

In this example, the first five columns are strings: region, state, city, store ID, and product. These are followed by three numbers, representing current sales, last year's sales, and the sales target. (The specific mapping to those values is defined in the configuration file, described in the section "The Configuration File.")

The data file cannot contain blank lines or comments. Missing or extra data on a line causes an error.

**Note:** One tab (the default separator) separates each field. Do not insert multiple tabs to line up the fields visually; doing so generates blank fields. It is possible to use other characters, such as a colon (:), as a separator. In this case, the first line appears as:

```
Eastern:Maryland:Baltimore:1816:appliances:72:115:138
```

The order of the columns must match the format of the configuration file. The order of the rows affects the layout of the final graphic, unless the configuration file specifies sorting. Generally, objects appearing earlier in the file appear to the left of objects appearing later in the file.

Any field in the data can also be a "?", indicating that the data is null (unknown). See Appendix J, "Nulls in MineSet."

## Data Types

The Tree Visualizer supports integer, floating-point number, and string data types, as well as arrays of these types. The following data types are supported:

- **int** represents a 32-bit signed integer.
- **float** represents a single-precision floating point number. The decimal point is optional. Numbers in exponential "e" notation are also accepted.
- **double** represents a double-precision floating point number. The decimal point is optional when representing a floating point number. Numbers in exponential "e" notation are also accepted. The superior precision of **double** can be useful for accurately representing large numbers, since **float** can represent only seven or eight significant digits accurately. This superior accuracy, however, consumes twice the memory space of **float**.

- **dataString** represents a string that is unlikely to appear multiple times. If it appears multiple times, several copies are made. A **dataString** can be used to store a memory address. Addresses are unlikely to be compared, and each record can have a different address.
- **string** represents a string of characters that can appear multiple times in the data file. Unlike a **dataString**, only a single copy of a given string is stored in memory, no matter how many times it appears in the data. This saves memory for strings appearing many times.

  Comparing **strings** is also much quicker than comparing **dataString**s. Reading in **strings** can be slower than reading in **dataStrings** because it is necessary to look for duplications. An example of **string** use is a division name that appears once for each department in the division. If you are unsure whether to use a **string** or a **dataString**, use a **string**.
- **fixed string** represents a string of fixed length. Like a **dataString**, if a **fixed string** appears multiple times, multiple copies are made. In general, **fixed strings** are used internally for representations of data from data bases, and are generally better to use than **strings** or **dataStrings**.
- **date** represents a date and time. In the data file, **date** must appear in the format MM/DD/YY HH:MM:SS.

## Enumerations

You can create a special data type that maps consecutive integers to strings. These types are referred to as enumerations, or enums. For example, you can create a state enum that maps 0 to Alabama, 1 to Alaska, and so on. Often, enums are created by the Tool Manager to represent bins. For example, 0 might map to a bin representing <10, 1 to the bin 10-20, and so on.

## Arrays

With the Tree Visualizer, you can use one-dimensional arrays of fixed or variable size.

In a fixed-sized array, all entries of the given type have the same number of values. For example, the budgets of the 50 United States can be represented by a separate float column for each state, or by a single array with 50 floats.

A special form of a fixed array is an “enumerated array.” Like the normal fixed array, there are a fixed number of values in the array; however, the values are associated with an enumeration. For each value in the enumeration, there is a single entry in the array. For example, if there is an enumeration representing the 50 states, an enumerated array based on this enumeration has 50 values. (Note that in MineSet release 1.0, the enumerated array was referred to as a “keyed fixed array.”)

A variant of the “enumerated array” is the “null enumerated array.” This is a variant of the enumerated array with an additional entry at the beginning for null (represented as a “?” ). For example, with the enumeration of the 50 states, the null enumerated array has 51 values, one for NULL, and the remaining 50 for the 50 states. The null array element could be used for entries where the state is unknown.

A variable-length array can have a different number of entries in each instance of the array. Often this is useful for representing organizations in which different parts have different depths. For example, one department could be represented by Gomez:Shapiro:Lacy (three entries), while another is Gomez:Wong:McMartin:Singe (four entries).

A variable-length entry with zero values can also be declared by passing an empty string. This can be used to specify data for the top level of a hierarchy.

When representing an organization with variable-length arrays, be careful. The Tree Visualizer computes the height for each level of the hierarchy separately, giving the highest bar on each level a user-specified height and normalizing the other bars accordingly. For example: Imagine a U.S.-based organization with a domestic and an international sales force. Domestic sales are divided up into states, which are further divided into cities. International sales are divided into continents, which are then divided into countries and cities. You can have locations such as domestic:California:Mountain View, and international:Europe:Italy:Rome. When displaying organizational hierarchies of this type, it is best to normalize heights at each level. If this is not done, small parts of the organization (for example, Mountain View) would be dwarfed by large parts of the organization (for example, domestic).

When the system tries to match up the levels, the normalization process might introduce anomalies. Usually, this is not the case at the highest level (domestic is matched with international); however, at lower levels this correspondence is no longer valid. Domestic cities (for example, Mountain View) are at the third level, but the third level for international is a country (for example, Italy). Comparing domestic cities against foreign countries usually has little validity. In this case, it is recommended that you introduce artificial levels to balance the hierarchies (for example, domestic:USA:California:Mountain View), thus matching cities.

Variable-length arrays might also be useful when some of the regions being compared are subdivided further than others. For example, an organization might have USA:California:San Francisco and USA:California:Los Angeles, but only USA:Wyoming. There is no need to construct an artificial third level just to keep the arrays balanced, as long as each level in the array matches the same level in other arrays.

Starting up the Tree Visualizer takes longer when variable-length arrays are read in than when fixed-length arrays or individual columns are read in. Unless the data is variable length, it is best not to use variable-length arrays.

As with the columns, arrays are represented as values separated by tabs or other separators. For a fixed-sized array, the same separator can be used for columns and for individual array elements (in which case, array elements are not visually distinguished from separate columns). You can also define a different separator. In the sales example (in "The Data File" on page 531), for example, you can treat the location as a four-element array, rather than as four columns. It then could be represented like this:

```
Eastern:Maryland:Baltimore:1816	appliances	72	115	138
```

Here, the array is separated by colons, and the columns are separated by tabs. (For clarity, the rest of this document uses tabs to separate columns, and colons to separate array elements.)

For a variable-length array, you must use different separators for the array and for the columns; otherwise, it is impossible to determine where the variable-length array ends and the other columns begin.

## The Configuration File

The configuration file format is flexible. Words in it must be separated by spaces, and it is case-sensitive. Except for the include statement and text within quoted strings, spacing and line breaks are irrelevant.

Comments begin with a pound (#) symbol at the beginning of a line; anything after this symbol to the end of the line is ignored.

### Sections

The configuration file consists of a series of sections, each of which has this syntax:

```
sectionKeyword
{
    statements...
}
```

where *sectionKeyword* names the section. A semicolon (;) can follow the closing brace (}) but is not required. The order of the sections is significant, since sections can refer to variables defined in previous sections.

### Options Files

As each section is encountered, a special configuration file (referred to as an "options file") is also read in. Options files have names in the form:

*sectionName*`.treeviz.options`

Options files normally contain options statements. These files are read in the following order:

1. The directory */usr/lib/MineSet/treeviz*. This directory usually contains system defaults.
2. The *~/.MineSet* directory (where the tilde, ~, indicates your home directory). You can set up personal defaults in this directory.
3. The current directory. This lets you set up defaults for each directory.

Files with the same name can appear in more than one of the above-named directories; in this case, the order given is the one in which the directories are read. If the same option is found in multiple files, the last option read is used. Note that the appropriate section in the configuration file is read after all the options files have been read in; thus, options in the configuration file override those in the options files.

### Statements

A statement has the following syntax:

```
statementKeyword info ;
```

where *statementKeyword* defines the statement, and *info* varies according to the keyword. A statement can be another section (using the brace format defined under "Sections").

### Variable Names

A variable name can appear in two formats:

- In the first format, it is a letter followed by a number of letters, digits, or underscores. It cannot be a keyword (defined later in this appendix), and should not be placed in quotation marks.
- In the alternate form, the variable name should be surrounded by back quotes (`‘`). In this form, the variable name can match a keyword, and can contain even non-alphanumeric characters. The primary purpose of this second form is for configuration files generated automatically by the Tool Manager.

There is no scoping of variable names; a given variable name can be declared only once in the configuration file.

### Option Statements

Many sections have options statements, which have this syntax:

```
options key info, key info... ;
```

where *key* defines the specific option, and *info* depends on the key. In some cases, the *key* can be more than one word. To maximize the number of allowable variable names, most option keys are meaningful only within the appropriate option statement; keys do not conflict with variable names. You can declare several options on the same line, separating them by commas or placing them in several options statements. For example, the following two examples are equivalent:

```
options home angle 30, shrinkage 10.0;
```

and

```
options home angle 30;
options shrinkage 10.0;
```

If two conflicting values for the same option appear, the last value is taken.

## Include Statements

The configuration file can contain lines of the form:

```
include "filename"
```

These lines can appear anywhere in the configuration file, but each must be on its own line. The filename must be in quotation marks; anything after the closing quotation mark is ignored. Include statements can be nested. If a relative pathname (one not beginning with a slash) is specified, the file is first sought relative to the directory containing the current configuration file. (If include statements are present, this might not be the same as the initially loaded configuration file.) If it is not found in the directory containing the current configuration file, the include file is sought in the current directory. If the file is not found, an error message appears.

## Sinclude Statements

A statement similar to an include is sinclude, which has the syntax:

```
sinclude "filename"
```

This is identical to the include statement, except that no error appears if the file does not exist; instead, the sinclude statement is ignored.

## Strings and Characters

Strings and characters in the configuration file follow C language conventions. Strings are in double quotes ("), and characters are in single quotation marks (‘). All standard backslash conventions are followed (for example, \n represents a new line).

## Keywords

The currently recognized keywords are listed in Table B-1. Variables cannot have these names unless they are surrounded by back quotes (‘). Tokens appearing only in option statements are not keywords, and can be used for variable names.

**Table B-1** Keywords for the Tree Visualizer

aggregate
any
ascending
average
back
base
buckets
color
colors
count
dataString
descending
disk
divide
double
enum
execute
expressions
file
filter
float
height
hierarchy
input
int
isSummary
key
label
landscape
legend
levels
max
message
min
modulus
none
normalize
off
on
options
scale
separator
sort
string
sum
view

## Expressions

Expressions are accepted in several places in the input. Expressions follow standard C syntax. The following operations are supported:

```
 +  -  *  /  %  ==  !=  >  <  >=  <=  &&  ||  !  &  |  ^  ?:
```

Also, the following functions are available:

- **divide**(x, y, z) divides *x* by *y*, unless *y* is zero. If *y* is zero, the result is *z*; this is equivalent to the C construct *y==0 ? z : x/y*.
- **modulus**(x, y, z) is similar to **divide**, but for modulus.
- **hierarchy**(*string*) is valid only within a hierarchy. It produces a string describing the components of the hierarchy, separated by *string*. For example:

  ```
  hierarchy(":")
  ```

  might produce

  ```
  Western:California:Mountain View
  ```

  The hierarchy function is most useful in the execute statement, passing the hierarchy information to the command being executed.
- **isSummary**() returns 1 if the expression is being applied to base information; otherwise, it returns zero. Often, this is useful with the **?:** operator, particularly in message and execute statements.

Type handling is similar to that in C. Expressions using **int** and **float** promote both sides to float. Expressions using **int** and **double**, or **float** and **double** promote both sides to double. The result of a relational expression (for example, ==, <) is always an **int**. Type casting is also supported.

Unlike in C, strings can be compared using relational expressions; the strings are compared lexicographically.

# The Input Section

The first section of a data file is normally the input section. It defines the name and format of the file. A typical input section might look like this:

```
input {
   file "store";

   string region;
   string state;
   string city;
   string storeId;
   string product;
   float sales;
   float lastYear;
   float target;

   options separator ‘:’;
}
```

This example states that the input file is called *store*, and that there are eight fields: five of type **string**, three of type **float**.

When the input section is entered, the options file, *input.treeviz.options*, is read in.

## File Statements

The file statement names the data file to be read. This statement is required. Its syntax is:

```
file "filename";
```

*Filename* must be in double quote marks. If it is a relative pathname (no leading slash), it is first sought in the directory containing the current configuration file. If include statements are present, this might not be the same as the initially loaded configuration file. If it is not found in the current configuration file’s directory, the file is sought in the current directory.

## Data Statements

The data statements declare the columns in the data file. The columns must be declared in the order they appear in the data file. The format of most data statements is

```
type name;
```

where *type* is **int**, **float**, **double string**, **dataString**, **date**, and **fixedString(*n*)**, where *n* is an integer representing the width of the string; *name* is the variable name. Unlike in C, only one variable can be declared per statement.

### Enumerations

The syntax for declaring an enumeration is:

```
enum type name { value, value...};
```

For example:

```
enum string state {
   "Alabama",
   "Alaska",
   ...
   “Wyoming"
};
```

The word “string” indicates that the enumeration maps integers to strings; they can also be mapped to other types.

Note that for compatibility with MineSet 1.0, “enum” can be replaced with “key.”

Once an enumeration is declared, a column can be declared to be of that enumeration using the following syntax:

```
enum enumname columnname;
```

For example:

```
enum state st;
```

declares `st` to be a variable of state enumeration. The input file corresponding to this column must contain values from 0-49 (or “?” representing null); however, the output shows the state name.

Enumerations also can be used to declare enumerated arrays (see “Enumerated Arrays”).

### Fixed Arrays

Arrays are also declared using data declarations. The simplest form is the fixed array. The declaration syntax is

```
type name [ number ] ;
```

For example:

```
float revenue [50];
```

You can also override the separator by declaring it as

```
type name [ number ] separator ‘char’;
```

For example:

```
float revenue [50] separator ‘:’;
```

If no separator is specified, the default column separator (usually a tab) is used.

### Enumerated Arrays

To declare an enumerated array, first declare the enumeration (see the “Enumerations” subsection). Then declare the array using the following syntax:

```
type name [ enum keyname ];
```

or

```
type name [enum keyname ] separator ‘char’;
```

For example:

```
float revenue [enum state];
```

As with the normal fixed array, you can also specify a separator. Note that for compatibility with MineSet 1.0, the word "enum" can be omitted from within the brackets. To declare a null enumerated array, use the syntax:

```
type name [ null enum keyname ];
```

or

```
type name [ null enum keyname ] separator `char';
```

For example:

```
float revenue [null enum state];
```

indicates that the array contains one additional value at the beginning, corresponding to null.

### Variable-Length Arrays

To declare a variable-length array, do not include a number in the brackets ( [ ] ). With a variable-length array, you must include a separator that is different from the one specified as a column separator. The syntax is:

```
type name [] separator ‘char’;
```

For example:

```
string category [] separator ‘:’;
```

## Input Options

The input section of a data file has several options. All options statements begin with the word *options* and have one or more comma-separated options.

- The separator option defines the separator between columns in the data file. The default separator is a tab. The syntax is:

  ```
  options separator ‘char’;
  ```

  For example:

  ```
  options separator ‘:’;
  ```

  **Note:** Arrays can override the separator.

- The monitor option allows a dynamic update of the data displayed. When the specified file is changed (for example, through the *touch* command), the data file (not the configuration file) is reread. The data file should not be used to trigger the updates. This prevents the data file being read at the same time it is being updated. The syntax of the monitor option is

  ```
  options monitor "filename";
  options monitor "filename" timeout;
  ```

  where *filename* is the file to watch, and the optional *timeout* specifies the number of seconds to wait after the file changes. If the user interacts with the application in any way during this timeout (via the mouse or keyboard), the timeout restarts. Updating the file can take a few seconds. By specifying a timeout, the chances of an update occurring while the user is interacting with the tool are minimized (but the update is delayed). If no timeout is specified, the update occurs immediately.

The file being monitored must exist at the start of the program. When this file is being updated, it must not be removed and re-created; instead, only its modify time should be updated (for example, through the *touch* command). If the file is deleted, subsequent updates are not shown.

Suppose a program extractor extracts data from a database into a data file. If you want the program to update the data file every 10 minutes, the script might look like this:

```
extractor > dataFile;        # create first data file
touch trigger;               # create the trigger file
while (sleep 600)            # sleep 10 minutes
do
   extractor > dataFile;     # create new data file
   touch trigger;            # force a reread
done &                       # this loop goes in the
                             # background
treeviz configFile;          # run treeviz
kill $!                      # when treeviz exits, kill the
                             # update loop
```

The monitor option can be used only if the file alteration monitor */usr/etc/fam* is installed (this can be found in the subsystem *desktop_eoe.sw.fam*).

The input section of a configuration file might look like this:

```
input
{
   file "dataFile"
   #data declarations here
   options monitor "trigger" 15;
}
```

- The backslash option controls whether backslashes in the input data are treated specially or like other characters. The syntax is:

```
 options backslash off;
 options backslash on;
```

The default is off. If backslash processing is on, separators in the input data preceded by backslashes are treated as regular characters rather than separators. Also, within strings standard C-style backslash processing is done.

## The Expression Section

The expression section of a data file lets you define additional columns that are expressions of existing columns. For example, one column can be defined as the sum of two other columns. The expressions are calculated before the definition of the hierarchy. In many cases, it is more appropriate to apply the expressions after creating the hierarchy; the expressions then should be defined within the hierarchy section (described later), and the expressions section can be omitted.

The following is a sample expression section. This section assumes two existing columns of type **float**, "male" and "female"; these represent spending by males and females on various goods. Two columns are added: "total" represents the total dollars spent, and "pctFemale" represents the percentage of dollars spent by females.

```
expressions
{
float total = male+female;
float pctFemale = divide (female*100, total, 50.0);
}
```

**Note:** The pctFemale calculation uses "total," defined in the previous statement. Also, note the use of the divide function rather than the **/** operator. This results in 50% for the case where there are no dollars spent at all; using the **/** operator generates a divide by zero error in such a case.

The format of the expressions section is:

```
expressions
{
   expressionDeclaration;
   ...
}
```

where *expressionDeclaration* has the following syntax:

```
type name = expression ;
```

Since the expressions section has no options, no options file is read in for it.

## The Hierarchy Section

The hierarchy section of a data file describes how the previously read table is converted into a hierarchy. Here is a sample hierarchy section:

```
hierarchy
{
   levels region, state, city, storeId;
   key product;
   aggregate
   {
      sum sales;
      sum lastYear;
      sum target;
   }
   expressions
   {
      float pctLastYear = divide(sales*100, lastYear, 100.0);
      float pctTarget = divide(sales*100, target, 100.0);
   }
}
```

The parts of the hierarchy section are described below.

When entering the hierarchy section, the *hierarchy.treeviz.options* options file is read in.

### Levels Statements

The levels statement defines how the table is converted into a hierarchy. The format is:

```
levels name, name...;
```

where *name* represents a column previously defined in the input or the expressions section. How the hierarchy is created depends on the types of the columns defined.

If the columns represent simple types (for example, strings or numbers), each column is converted into a single level of the hierarchy. The top level of the hierarchy is a single, all-inclusive node. The next level contains one node for each unique value in the first column. The third level contains one node for each unique value in the second column, and so on. Hierarchies created in this way are always balanced: All branches in the hierarchy go to the same depth (namely one greater than the number of columns specified in the levels statement).

In the case where the column is an array, there can be only a single column specified in the levels statement. Each value in the array is mapped to one level in the hierarchy. The top level is a single node representing the total aggregation. The next level contains one node for each unique value of the first value in the array; the third level contains one node for each unique value of the first two values of the array, and so on.

If the array is of fixed type, this hierarchy is balanced. If a variable array is used, the hierarchy is not necessarily balanced (some branches can go deeper than others).

A variable-length array can be used to specify the hierarchy, even if the hierarchy is balanced to a fixed depth. When using columns or fixed arrays to specify the levels, you can specify data associated only with those levels at the bottom (or leaf) nodes. In this case, all higher nodes in the hierarchy must be aggregated. However, rather than relying on automatic aggregation, you might want to supply your own data for each level of the hierarchy (if, for example, the calculation can not be done automatically by the Tree Visualizer). In that case, use variable-length arrays to specify levels and provide separate data for each level.

For example, the data file might contain lines such as:

```
Domestic:Western  43
Domestic:Eastern  57
Domestic    85
Intl:Europe  52
Intl:Asia  39
Intl   94
      133
```

**Note:** The last line has an empty value for the location; the number 133 is translated to the top of the hierarchy.

## Key Statements

The key statement specifies those keys that are used to select the bars at each node in the hierarchy. The key corresponds to the bars displayed in the final view. The syntax of the key statement is:

```
key name [sort [ascending|descending]};
```

where *name* is the name of one of the previously defined columns. It cannot be the name of a column used in the levels statement. Only a single key statement can be made.

By default, the bars generated by the key statement appear in the order first encountered. If the key is an enumerated array, the bars appear in the order of the enumeration; otherwise they appear in the order in which values are first encountered in the data file. Adding the word `sort` at the end of the key statement sorts the bars. Sorting depends on the type: Strings are sorted alphabetically, and numbers are sorted numerically. Enumerations are sorted on the index of the enumeration, not the string that the enumeration refers to. If, however, the key is an enumerated array, the sorting takes place according to the enumeration string (to sort based on the enumeration index, leave it unsorted). Optionally, the word `sort` can be followed by `ascending` or `descending` to specify the sort order; the default is ascending.

If the key column is a simple type (for example, a **string**), the unique values of that key are looked up in the original table. The order of the values is the same as the one in which the key values appear in the original input table. Although it is not required, the same keys are often repeated in the same order. For example, in the following table, the fifth column is the key, and has the values “appliances,” “clothing,” “electronics,” and “furniture.”

```
Eastern  Maryland  Baltimore  1816 appliances  72  115  138
Eastern  Maryland  Baltimore  1816 clothing  355  344  395
Eastern  Maryland  Baltimore  1816 electronics  156  182  209
Eastern  Maryland  Baltimore  1816 furniture  78  75  82
Eastern  Massachusetts  Boston  1331 appliances  48  68  81
Eastern  Massachusetts  Boston  1331 clothing  307  258  296
Eastern  Massachusetts  Boston  1331 electronics  38  183  210
Eastern  Massachusetts  Boston  1331 furniture  52  69  75
Eastern  Massachusetts  Boston  1220 appliances  37  63  75
Eastern  Massachusetts  Boston  1220 clothing  233  240  276
Eastern  Massachusetts  Boston  1220 electronics  175  208  239
Eastern  Massachusetts  Boston  1220 furniture  35  53  58
```

The key can also be any column of the enumerated array type. In this case, the enumeration is used as the key for specifying the bars. Other columns in the input can also be enumerated array types, as long as they use the same enumeration. For example, this table can also be input as

```
Eastern  Maryland  Baltimore  1816
              72:355:156:78  115:344:182:75  138:395:209:82
Eastern  Massachusetts  Boston  1331
              48:307:38:52  68:258:183:69  81:296:210:75
Eastern  Massachusetts  Boston  1200
              837:233:175:35  63:240:208:53  75:276:239:58
```

For clarity, each line has been wrapped onto two lines; however, in the file these should be on single lines. The input section for this data appears as

```
input
{
   file "...";
   key string product {
   "appliances", "clothing", "electronics", "furniture"
   }
   string region;
   string state;
   string city;
   string storeId;
   float sales [ enum product ] separator ‘:’ ;
   float lastYear [ enum product ] separator ‘:’ ;
   float target [ enum product ] separator ‘:’ ;
}
```

**Note:** Since the arrays are fixed, the use of a colon separator for the arrays is not required; however, it might make it easier for a human to read the input.

In this example, the hierarchy section appears as follows:

```
hierarchy
{
   levels region, state, city, storeId;
   key sales;
   ...
}
```

Since *sales* is an enumerated array, it used its key type (product) as the key to generating the bars; thus, each graph in the final view has four bars. Note that *lastYear* and *target* must use the same key type for their array.

Arrays other than enumerated arrays can not be specified as the key.

## Aggregate Subsection

The aggregate subsection of the hierarchy section describes how values are aggregated at higher levels of the hierarchy. An example is:

```
aggregate
{
   sum sales;
   sum lastYear;
   sum target;
}
```

This indicates that *sales*, *lastYear*, and *target* are to be summed at higher levels of the hierarchy (each level summing the values in the level below it). In addition to the **sum** aggregation, the aggregations **average**, **min**, **max**, **count**, and **any** are allowed. All are self-explanatory, except for **any**, which indicates that any of the values can be used. This aggregation is used if you expect the same value (for example, a string) to appear everywhere in the hierarchy and if you just want it to populate the entire hierarchy.

A special case is when the key is an enumerated array. Here, the key is normally also aggregated.

In the case where a variable-length array specifies data for all levels of the hierarchy simultaneously (as opposed to merely specifying the data at the leaf nodes), the aggregate section cannot be used.

The two forms an aggregate statement can take are

```
agg name;
name1 = agg name2;
```

In both cases, the aggregate (*agg*) is one of **sum**, **average**, **min**, **max**, **count**, and **any**. The first form was illustrated above; it aggregates a column, and the result is given the same name as the original column being aggregated. The second form aggregates the column *name2*, but gives the result the name *name1*. This second form is useful if the same value is being aggregated multiple times. Since using the first form creates two aggregations with the same name, the second form can be used to differentiate the aggregations.

For example, if you have a column named *expenses* and want to aggregate it to show the maximum and minimum expenses, you can use

```
aggregate
{
   maxExpenses = max expenses;
   minExpenses = min expenses;
}
```

## Aggregate Base Subsection

This subsection specifies how values in the base are aggregated. It can be used only if the aggregate subsection is not present. (If the aggregate section is present, the base is aggregated using the aggregations specified in it).

A sample aggregate base subsection is:

```
aggregate base
{
    sum sales;
    sum lastYear;
}
```

An aggregate statement takes the form

```
agg name;
```

where the *aggregate* (*agg*) is one of sum, average, min, max, count, and any, (similar to the aggregate section). The aggregation is applied to all the bars on that base to give the appropriate value for the base. After the base is aggregated, its values correspond to all of the columns used in specifying the bars. Any column not specified in the aggregate base section has a value of zero. Because the base values correspond to the bar values, the second form of the aggregate statement (using the =), cannot be used in the aggregate base section.

## Expressions Subsection

An expressions subsection of the hierarchy section is similar to the expressions section described earlier, except that it is applied after the hierarchy is created and aggregated. The syntax is identical, but it is declared within the hierarchy section, not external to it.

To give an example of the difference between calculating the expressions before and after creating the hierarchy, take the example of male and female dollars spent. Assume you want to calculate the percentage of dollars spent by women. The expressions might be:

```
expressions
{
   float total = male+female;
   float pctFemale = divide (female*100, total, 50.0);
}
```

Assume you calculated these variables before creating the hierarchy. Then, when aggregating the data up the hierarchy, summing the percentages is not useful. Averaging the percentages results in a believable number; however, it averages percentages of large dollars with percentages of small dollars, and produces incorrect results. (To make this clearer, suppose that on one product, males spent $99, and females spent $0. On another product, males spent $0, and females spent $1. On the first product females spent 0%, and on the second they spent 100%. Averaging these gives 50%, but in reality, females spent only 1% of the dollars spent on the two products combined.)

The base data should be aggregated first, then the expressions should be applied. (In the example, after aggregating, the result is a combined spending of $99 for males, and $1 for females; if the percentage is calculated after the aggregation, the correct value of 1% results.)

## Sort Statements

By default, the order of the nodes within each level of the hierarchy is based on the order of the data in the input file. However, sometimes it is desirable to sort the hierarchy. The sort statement can appear in one of two forms:

```
sort name [, ascending|descending];
sort key [, ascending|descending];
```

In the first form, one column name (not used in the level statement) is used for sorting. The column can be the result of an aggregation or an expression. In the second form, the value used in the level statement is the one used in laying out the hierarchy.

The hierarchy can be sorted in ascending or descending order. If neither option is specified, the default is descending order if the first form of the sort is used (this places the largest columns on the left); the default is ascending order if the second form is used (this typically sorts alphabetically).

Note that sort statements affect the sorting of only the branches of the hierarchy; they do not affect the bars within each node of the hierarchy.

## Hierarchy Options

There are two options in the hierarchy section: *skipMissing* and *organization*. The format for the *skipMissing* option is

```
options skipMissing;
```

If this option is off (the default) and some values of the key are not present for a given hierarchy node, dummy entries are created with values of 0. This guarantees that all graphs in the hierarchy have the same number of bars, and the same layout. If this option is on, no such entries are generated. This results in variable-length tables in the hierarchy, and bars exist only for items in the input. The position of these bars, however, is not meaningful. This option is not useful if the key is an enumerated array (for which all values are supplied).

The *skipMissing* option increases memory usage and should be avoided, if possible.

The format for the *organization* option is

```
options organization same;

options organization contains;

options organization unknown;
```

The organization option provides hints about the hierarchy organization that allow for more efficient algorithms. This option is most useful if no hierarchy aggregation is done. The *same* value specifies that all nodes in the hierarchy contain entries for the same item (for example, all nodes could contain “appliances,” “clothing,” “electronics,” and “furniture”). The *contains* value indicates that a parent node contains entries for all values that its children contain. For example, if a node contains “appliances,” its parent node must also contain “appliances,” although not all of its child nodes must contain appliances. The *unknown* value means that no assumptions are to be made regarding the contents of individual nodes.

If no organization is specified, the Tree Visualizer determines the organization as follows.

- If there is no aggregate subsection, *unknown* is used.
- If there is an aggregate section, but the *skipMissing* option is provided, *contains* is used; otherwise, *same* is used. Since this is normally correct when an aggregate subsection is provided (unless *skipMissing* is used but nothing is missing), there normally is no need to provide an organization if the aggregate subsection is present.

If the organization specified does not match the data, the results are unspecified. For example, *same* should not be specified, unless all nodes have the same entries.

## The View Section

The view section of a data file describes how the hierarchy is displayed, including the mapping of heights, colors, labels, and so forth. A sample view section is:

```
view hierarchy landscape
{
   height sales, normalize levels, max 2.0;
   height legend label "Height: Total sales";
   base height max 1.0;
   disk height target, legend label "Disk height: Target
             sales";
   color pctTarget, scale 0 100 200 500;
   color colors "red" "gray" "green" "blue";
   color legend label "Color: % of target" "0%" "100%"
             "200%" "500%";
   options columns 4;
   message "$%,.2f, %.0f%% of target, %.0f%% of last year",
             sales, pctTarget, pctLastYear;
}
```

The first words of the view section (before the opening brace) describe the type of view. The only view type supported is **view hierarchy landscape**; thus, these words must introduce the view section.

When entering the view section, the *viewHierarchyLandscape.treeviz.options* options file is read in. Note that there is not a simple *view.treeviz.options* options file, the full name *viewHierarchyLandscape* must be used.

## Height Statements

The height statement describes how the columns are mapped to the height of objects. It consists of a series of clauses separated by commas. Alternatively, it can be specified as multiple height statements. Thus: the following three examples are equivalent:

-
  ```
  height sales, normalize levels, max 2.0;
  ```

-
  ```
  height sales;
  height normalize levels;
  height max 2.0;
  ```

-
  ```
  height sales, normalize levels;
  height max 2.0;
  ```

The first clause normally contains the name of a column that is to be mapped to height (“sales,” in the example). The column must be of a number type (**int**, **float**, or **double**); **float** is the most efficient. If no height column is specified, all bars are flat, and the remaining height clauses have no effect.

### Normalize Clause

The normalize clause determines the maximum value of the height variable; it normalizes all values relative to that height. Thus, if the maximum value is 30.0, and that bar was given a height of 1.0 (in arbitrary units), a value of 15.0 would be mapped to a value of 0.5.

The syntax of the normalize clause can be

normalize
This normalizes all values against one another, throughout the hierarchy.

normalize levels
This performs independent normalization at each level of the hierarchy.

normalize none
This performs no normalization, and is the default.

The second form is particularly useful in cases where the data is aggregated up the hierarchy. For example, assume the sales data is aggregated up the company. Comparing the sales of the company as a whole to the sales of a single individual has little meaning; in a large company, the heights of the bars for the individuals are so small as to be indistinguishable from zero. It makes more sense to compare sales people to sales people, offices to offices, regions to regions, and so on. Normalizing levels does this.

Regardless of which form of normalization is used, the base (if shown) is always normalized independently of the bars. By default, the same normalization mechanism for the bars is used for the base.

### The scale Clause

The scale clause scales the height of all objects; all values are multiplied by the scale. The syntax of the scale clause is:

```
scale float
```

where *float* is a floating point number (the decimal point is optional). For example, to double the heights, specify

```
scale 2
```

### The filter Clause

Large datasets can contain many graphics. This results in poor performance. In many cases, the data values are small and of little informative value. The filter clause prefilters the data based on the height variable, so that only the nodes with the highest bars are shown. The syntax of the filter clause is:

```
filter > float%
```

The > and % characters must be typed literally. For example:

```
filter > 5%
```

This example filters out all charts containing no bars greater than 5% of the maximum bar height, except for those containing descendants in the hierarchy containing such bars. Note that if a chart contains just one bar that meets this criterion, the entire chart is shown.

The filter value can be changed interactively through the filter panel (see “The Filter Panel” in Chapter 5).

The filter clause is permitted only on the height statement.

### The legend Clause

The legend clause defines the meaning of the height mappings. Any string can be placed in the height legend. The legend clause has the following syntaxes:

legend off This turns off the height legend (this is the default).

legend on This turns on the height legend.

legend label *string*
This changes the legend. If legend label is used, legend on is unnecessary.

By default, the legend has the following syntax:

```
height:varname
```

where *varname* is the name of the variable that is mapped to height.

It is possible to declare separate legends for the height, the base height, and the disk height.

## Base Height Statements

The base height statement specifies how the height of the base is calculated. The format is similar to the height statement, except that it is preceded by the word “base.” If the base height statement is omitted, the height of the base is calculated using the same values as in the height statement (the same variable, normalization mechanism, max value, and so on). You also can specify only some of the clauses for the base, in which case everything else is the same as the height statement. For example:

```
height sales, normalize levels, max 2.0;
base height max 1.0;
```

In this case, the base height is based on *sales*, and it is normalized by *levels*. The maximum height, however, is only 1.0 instead of 2.0. Usually, the visual effect is better if the base height max is less than the max for the bars.

The filter clause is not permitted on the base height statement.

### The on and off Clauses

The initial value of the base height can be turned on and off via the on and off clauses. To turn it off, use

```
base height off
```

To turn it on, use the default:

```
base height on
```

The base height can be changed interactively using the Base Height option in the Display menu. The on and off clauses are valid only with base height. Do not use them with the height or disk height statements.

## Disk Height Statements

You can place a disk on each bar to indicate an additional item of data. This is done with the disk height statement. The disk height statement's syntax is similar to that of the height statement, but it is preceded by the word "disk." For a disk to be displayed, there must be a clause specifying the column to be mapped to the disk. Other clauses are optional; if these are omitted, the height statement's defaults are used.

If the height statement has a normalize clause, and the disk height statement has no normalize or max clause, then the disks are normalized with the bars (they are drawn to the same scale). If the disk height statement has either a normalize clause or a max clause, the disks are normalized independently of the bars. For example:

```
height sales, normalize levels, max 2.0;
disk height target;
```

In this case, the bars are mapped to the variable "sales," and the disks are mapped to "target." Both are normalized, with the maximum value of sales or target on each level mapped to a value of 2.0. If instead this example is written as

```
height sales, normalize levels, max 2.0;
disk height target, normalize levels;
```

the bars are mapped so the highest bar at each level is 2.0, and the highest disk on each level is 2.0, but the bars and disks are not mapped to the same scale. This can be used, for example, if the bars represent dollars and the disks represent head count.

The filter clause is not permitted on the disk height statement.

## Color Statements

The color statement describes how values are mapped to colors. The format is similar to that of the height statement, consisting of several clauses that can be separated by commas or entered as multiple statements.

### Color Naming

Color names follow the conventions of the X Window System™, except that the names must be in quotation marks. Examples of valid colors are "green," "Hot Pink," and "#77ff42." The last one is in the form "#*rrggbb*", in which the red, green, and blue components of the color are specified as hexadecimal values. Pure saturation is represented by ff, a lack of color by 00. For example, "#000000" is black, "#ffffff" is white, "#ff0000" is red, and "#00ffff" is cyan. (A list of available colors is found in the file */usr/lib/X11/rgb.txt*.)

### The Color Variable

As with height, you also can specify a single column to be mapped to a color. The column must be a number type. Unlike for height, there is no normalization of colors.

### The key Clause

Instead of specifying a variable, the word key can be specified. This assigns a different color based on each key, normally for each bar. For example, if the 50 states were the keys, key assigns a different color to the bar for each state. Since the base is not keyed, when the key clause is used, the base is always gray.

### The colors Clause

The colors clause specifies the colors to be used. The colors clause syntax is:

```
colors "colorname" "colorname"...
```

The format for *colorname* is described "Color Naming." Note that there are no commas between the colors. This is because commas are used to separate clauses in the color statement. A sample colors clause is

```
colors "red" "gray" "blue"
```

Colors in the list are subsequently referred to by their index, starting at zero. In the above example, red is color 0, gray is color 1, and blue is color 2.

If there is no colors statement, colors are chosen randomly; however, if there is a colors statement, at least as many colors must be specified as are to be mapped. If a key is used, there must be one color for each key value.

### The scale Clause

The scale clause allows assignment of values to a continuous range of colors. For example, when displaying a percentage, red can be assigned to 0%, gray to 50%, and blue to 100%. Intermediate values are interpolated; for example, 25% is pinkish, and 55% is a slightly bluish gray.

The syntax for the scale clause is

```
scale float float ...
```

The first value is mapped to color 0, the second to color 1, and so forth. The colors statement must contain at least as many colors as are to be mapped to the largest index.

Values in this statement must be in increasing order. Any value less than the first color is assigned the value of the first color. Any value greater than the last value is assigned the last color. Intermediate values are interpolated.

For example, assume the pctFemale column indicates what percentage of the group is female, and you want to map a group that is 100% female to red, 100% male to blue, and 50% each to gray. The colors statement for this is:

```
colors pctFemale, colors "blue" "gray" "red", scale 0 50 100;
```

### The buckets Clause

The buckets clause is similar to the scale clause without interpolation. All values are rounded down to the highest value in the clause, and that exact color is used. Values less than the first value use the first color.

The syntax for the buckets clause is

```
buckets float float ...
```

The syntax and assignment of colors is the same as for the scale clause.

If, in the `pctFemale` example, you used the buckets clause instead of the scale clause, the statement would be

```
colors pctFemale, colors "blue" "gray" "red", buckets 0 50 100;
```

All values greater or equal to 100 are colored red. Values greater than or equal to 50, but less than 100, are gray. All other values are blue.

### The legend Clause

The legend clause creates a legend of the colors. By default, a legend is on for the bar colors, and off for base and disk colors, although separate legends are permitted for each. The legend clause syntax can be any of the following:

```
legend off
legend on
legend "string" "string" ...
legend label "string"
legend "string" "string" ... label "string"
```

The **legend off** clause turns the legend off. The **legend on** clause turns the legend on. It can be omitted if other legend statements are included. Specifying only **legend on** generates the default legend.

The default legend includes a single label to the left (with the name of the column that is mapped to color), and a list of colored labels on the right (with values obtained from the scale clause, the buckets clause, or from the keys). To override the strings in the colored labels, specify the strings as: `legend "string" "string`.

To override the label on the left, specify it following the word label. To eliminate this label, specify an empty string; that is:

```
legend label ""
```

## Base Color Statements

The base color statement controls the color of the base. Its syntax is similar to the color statement, except that it is preceded by the word “base.” If this word is omitted, the base has the same color as the bars. If the base color statement is present, any omitted clauses default to the values of the color statement.

## Disk Color Statements

The disk color statement controls the color of the disk. The syntax is similar to the color statement, except that it is preceded by the word “disks.” If the disk color statement is omitted, the disk has the same color as the bars. If the statement is present, any omitted clauses default to the values of the color statement.

Since disks are drawn only if a disk height statement is present, a disk color statement has no effect without a disk height statement.

## Label Statements

Label statements specify the labels used when labeling objects in the scene. Normally, these statements can be omitted. By default, each bar is labeled with its key; each base is labeled with its position in the hierarchy. The syntaxes of the label statements are:

`label` *`name`*

`base label` *`name`*

`line label` *`name`*

`back label` *`name`*

where *name* is the name of the column to be used as the label. The first form is used as the label on the bars. The second form is the label on the bases. The third form labels the lines connecting the bases. The fourth places labels behind the bases. (Note that bases often obscure the back labels, so this form is less useful; however, there might be occasions where it is appropriate.)

## Message Statements

The message statement specifies the message displayed when the pointer is moved over an object or when an object is selected. The syntax is similar to that of the C **printf** statement. A sample message statement is

```
message "%s: $%f, %.0f%% of target, %.0f%% of last year",
      product, sales, pctTarget, pctLastYear;
```

This could produce the following message:

```
furniture: $2425.37, 23% of target, 87% of last year
```

The formats must match the type of data being used:

- Strings must use %s.
- Ints must use integer formats (such as %d).
- Floats and doubles must use floating point formats (such as %f).

For details of the **printf** format, see the printf (1) reference (man) page (type **`man printf`** at the shell prompt).

A special format type has been added to **printf**. If the percent sign is followed by a comma (for example, "%,f"), commas are inserted in the number for clarity. Currently, only the United States convention of d,ddd,ddd.dddd is supported, with the decimal point represented by a period, and commas separating every three places to the left of the decimal point. For example, if the above format were:

```
message "%s: $%,f, %,.0f%% of target, %,.0f%% of last year”,
      product, sales, pctTarget, pctLastYear;
```

it would produce the message:

```
furniture: $2,425.37, 23% of target, 87% of last year
```

The **$**, *, h, l, ll, L, and n **printf** format options are not supported.

All values, including the format string, are expressions. Thus, if you had a pctFemale column, but wanted a more gender-neutral message, you could use

```
message pctFemale>50?"%f%% females":"%f%% males",
      pctFemale>50?pctFemale:100-pctFemale;
```

If pctFemale is 70, the message "70% females" is displayed; if pctFemale is 30, the message "70% males" is displayed. In this case, you can also achieve the same result with a single format string:

```
message "%f%% %s", pctFemale>50?pctFemale:100-pctFemale,
      pctFemale>50?"females":"males";
```

By default, the same message is used for the base as for the bars. It is possible to specify a different message by using a base message statement, which has the same syntax.

If no message is specified, a default message containing the names and values of all the columns is used.

### The Execute Statement

The execute statement lets you execute a shell command by double-clicking an object. The syntax is similar to that of the *message* command; however, since hierarchy information is not displayed on a separate line, it is useful to include the hierarchy information and to pass the key information as arguments.

Here is a sample execute statement that uses *xconfirm* to show a window with information about the item. (The first line, the string, is broken into multiple lines to fit into a single page. In an actual file, it should be on a single line. Multi-line strings are not supported.

```
execute "xconfirm -t ‘%s’ -t ‘sales of %s’ -t ‘$%,.0f’
      -t ‘target $%,.0f (%.0f%% of target)’
      -t 'last year $%,.0f, %.0f%% of last year'>/dev/null",
   hierarchy(" "), isSummary()?"everything":product,
   sales, target, pctTarget, lastYear, pctLastYear;
```

This might produce a dialog with the message

```
Eastern Connecticut Milford
sales of clothing
$348
target $427 (81% of target)
last year $372 (94% of target)
```

Note the use of hierarchy(" ") to produce a blank-separated description of the hierarchy. Also note the isSummary()?”everything”:product; this produces the word “everything” if the base was selected, but otherwise produces the product. An alternative to this is using separate execute and base execute statements.

If there is no execute statement, double-clicking an object has the same effect as single-clicking it.

## The View Options

The view section has many options. Like other options statements, the options can be separated by commas, or they can appear in separate lines.

### Sky and Ground Colors

The sky and ground color can be specified using the following syntax:

```
options sky color colorname
options sky color colorname colorname
options ground color colorname
options ground color colorname colorname
```

The syntax for color names is the same as that for color naming.

For both the sky and the ground it is possible to specify either one or two colors. If only one color is specified, the sky or ground is solid. If two colors are specified, the sky or ground is shaded between the colors. For the sky, the first color is for the top of the sky, the second for the bottom. For the ground, the first color is for the far horizon, the second for the near ground.

For example, to have a solid black background, specify:

```
options sky color "black", ground color "black";
```

### Bar Layout

By default, bars in each chart are laid out as close to a square as possible. You can override this using either the rows or the columns option:

```
options rows number
options columns number
```

Only one of these can be specified.

### Overview

Although the overview can be brought up using the Show menu, it can also be configured to come up automatically at startup. The overview syntax is:

```
options overview on
options overview off
```

The first form causes the overview to be displayed at startup. The second form (the default) turns the overview off. Regardless of the setting, the overview can be invoked from the Show menu.

### Shrinkage

Hierarchies normally have a large aspect ratio, having greater width than depth. In their unaltered form, it is impossible to view the entire hierarchy, except from such a far distance that no detail would be visible. To see the hierarchy more clearly, distant objects can be shrunk more than perspective normally dictates. The shrinkage option lets you control the shrinkage for a given graph. The shrinkage option syntax is any of the following:

```
options shrinkage auto
options shrinkage float
options shrinkage off
```

The first form (the default) automatically calculates a shrinkage value. Its results are usually reasonable, but not necessarily optimal in unusual hierarchical layouts. Thus, you might want to explicitly set the shrinkage using the second form. For hierarchies in which some parts are deeper than others, automatic calculation does not work well. The best shrinkage value depends on the graph being displayed, as well as various layout options such as margins. You should experiment with each graph. Start with a value of 10.0, then make adjustments. Smaller values result in a narrower hierarchy and increased distortion. The shrinkage value must be positive; avoid values smaller than 5.0.

Shrinkage can be turned off. This is recommended only for very small hierarchies, as it produces hierarchies with very large aspect ratios.

### Root Label

By default, the root node of the hierarchy gets a label based on the name of the configuration file. You can override this by using the ***root label*** option. The format is

```
options root label string
```

This option also affects the string displayed when an object is selected, as well as the result of the of **hierarchy()** function.

Note that the root label option has no effect if the base label statement was used (that statement defines the base label for the root as well as for all other bases).

### Font

The font option controls the font used for drawing the labels. The syntax is

```
options font "fontname"
```

where *fontname* can be any font in the directory */usr/lib/DPS/outline/base*.

It also can be the string *default*. This attempts to use Helvetica (if available), or the default Inventor font (if Helvetica is not available). Note that different systems can have different fonts installed.

### Base Label Color

The base label color option controls the color of the labels in front of the bases. The syntax is

```
options base label color "color"
```

### Bar Label Color

The bar label color option controls the color of the labels in front of the bars. The syntax is

```
options bar label color "color"
```

### Line Color

The line color option controls the color of the lines connecting the nodes in the hierarchy. The syntax is

```
options line color "color"
```

### Zero

The zero option lets you determine whether bars, disks, and bases of height zero are drawn solid, as an outline, or hidden completely. In the last case, space is left for the object, but it is not drawn. The default value is solid. This option can be changed at run time using the Display menu (see “The Display Menu” in Chapter 5).

The syntax for the zero option is

```
options zero solid
options zero outline
options zero hidden
```

### Null

The null option lets you determine whether bars, disks, and bases of height null (see Appendix J, “Nulls in MineSet”) are drawn solid, outline, or hidden completely. In the last case, space is left for the object, but it is not drawn. The default value is outline. This option can be changed at run time using the Display menu (see “The Display Menu” in Chapter 5). The syntax is

```
options null solid
options null outline
options null hidden
```

### Other Options

There are 10 other options to control the layout of the display, level of detail, and other parameters. Generally, it is not necessary to adjust these parameters. The values of many of the options are in arbitrary units. Adjust the options by increasing or decreasing the value. For the default values of these parameters, see the file */usr/lib/MineSet/treeviz/viewHierarchyLandscape*.

- `options speed` *`float`*

  Controls the speed during free-form (middle-mouse) horizontal navigation (forward, backward, and side to side). The larger the value, the faster the motion.

- `options climb speed` *float*

  Controls the speed when moving up and down using Shift + middle mouse. The larger the value, the faster the motion.

- `options leaf leaf margin` *float*

  Controls the distance between adjacent nodes in the hierarchy. Larger values move the nodes farther away.

- `options root leaf margin` *float*

  Controls the distance between a node and its children. Larger values move the nodes farther away.

- `options leaf edge margin` *float*

  Adds margin space next to nodes at the edge of a subhierarchy.

- `options initial position` *float float float*

  Provides the initial *x*, *y*, and *z* position from which the scene is viewed. A value of 0 0 0 positions the viewer at the root of the hierarchy; since the user is looking forward, the root probably is not visible. Increasing *x*, *y*, and *z* moves the camera to the right, up, and back, respectively. A typical position has a zero *x*, positive *y*, and positive *z*. If unspecified, the initial position depends on the layout of the hierarchy.

- `options initial angle` *float*

  Provides the initial angle, measured in degrees, from which the hierarchy is viewed. The value must be between 0 and 90. A value of 0 looks at the scene horizontally; a value of 90 looks straight down.

- `options bar label size` *float*

  Specifies the size of the labels in front of the bars. Larger values result in larger labels.

- `options base label size` *float*

  Specifies the size of the labels in front of the bases. Larger values result in larger labels.

- `options lod [bar` ***`float float`***`] [bar label` ***`float`*** `[`***`float`***`]]`
  `[base` ***`float float`***`] [base label` ***`float`*** `[`***`float`***`]] [disk` ***`float`***`]`
  `[motion` ***`float`***`]`

  Controls the level of detail. The parameters can appear in any order, be omitted, or placed in multiple **lod** options. These options control the changing form, or disappearance of, objects, thus providing better system performance.

Except for the **motion** parameter, all float values represent the size of the object when the form change or disappearance takes place. The smaller the value specified, the smaller and farther away the object is when the change takes place. Smaller values provide nicer graphics but slower system performance. The numbers of the different parameters cannot be compared directly because the size of the object also determines when the change takes place. A value of 0.0 means no level of detail changes for that parameter. This setting can significantly slow the rendering process.

**bar** controls when a bar is drawn with less detail. The first value specifies when the object is drawn as a pair of planes; the second value specifies when the object is drawn as a single line.

**bar label** controls when the labels on the bars disappear. If two values are specified, the first value specifies when the label is drawn in a lower-quality, fast font; the second value controls when it disappears.

**base** controls when the bases, and the bar charts in front on top of them, disappear. The first number is based on the width of the base; the second on the height of the base plus the tallest bar on it.

**base label** controls when the label in front of the base disappears. If two values are specified, the first value specifies when the label is drawn in a lower-quality, fast font; the second value controls when it disappears.

**initial depth** controls the initial depth to which the hierarchy is viewed. When you are at the top of the hierarchy, you see only the number of hierarchical levels specified by the slider. The nodes in the rows are arranged to optimize their visibility. When navigating to nodes lower in the hierarchy, additional rows are made visible automatically. The nodes above them automatically adjust their locations to accommodate the newly added nodes; thus, some nodes might seem to move. Note that the overview shows all nodes in the hierarchy, not just the top nodes, so the layout of the overview might not match the layout of the main view. The X in the overview approximates the corresponding location in the main view; there is no exact mapping between the two layouts.

An initial depth of zero, or one greater than the depth of the hierarchy, shows the entire hierarchy.

Once the Tree Visualizer is running, the depth can be changed through the filter panel.

**disk** controls when the disk disappears.

**motion** controls changes in some of the level of detail calculations when the scene is animated. A value greater than 1.0 defaults to 1.0. A value of 1.0 specifies that motion has no effect on the level of detail. Smaller values change the level of detail at a proportional distance. For example, a value of 0.5 means that during animation, level of detail changes occur at half the normal distance.

*Appendix C*

# Creating Data, Configuration, Hierarchy, and GFX Files for the Map Visualizer

The first part of this appendix describes the types and formats of data supported by the Map Visualizer. Data input to the Map Visualizer must be provided as a single file containing raw data, usually in a tab-separated ASCII text form.

The second part discusses the configuration file, which describes how the Map Visualizer reads in, and displays, the data file.

Both the data and configuration files can be generated automatically by the Tool Manager (see Chapter 3).

**Note:** Read Chapter 6, "Using the Map Visualizer," before using this appendix.

## The Data File

In its simplest form, the data file consists of a list of lines, each containing a set of fields separated by one tab. (Other separators are also allowed, but only one can separate each field. See "Input options" on page 585.) All lines must contain the same fields. The interpretation of the fields is specified by the configuration file, described in "The Configuration File" on page 576. Using the U.S. population data (*examples/population.usa.data* file), provided as part of the Map Visualizer package, the first few lines of this input file appear as shown below:

```
AL    0 0 0 1000 9000 127901 309527 590756 771623 964201 996992
1262505 1513401 1828697 2138093 2348174 2646248 2832961 3061743
3266740 3444354 3894025 4040587    51705
AR    0 0 0 0 1000 14000 30000 98000 210000 435000 484000 803000
1128000 1312000 1574000 1752000 1854000 1949000 1910000 1786000
1923000 2286000 2351000    53187
AZ    0 0 0 0 0 0 0 0 0 0 10000 40000 88000 123000 204000 334000
436000 499000 750000 1302000 1775000 2717000 3665000    114000
CA    0 0 0 0 0 0 0 0 93000 380000 560000 865000 1213000 1485000
2378000 3427000 5677000 6907000 10586000 15717000 19971000 23668000
29760021    158706
```

In this example, the first column is a two-character string identifying the graphical object—the state. (This string locates a record in a *.gfx* file containing information about the shape of the graphical object.) The tab separator is followed by a grouping of 23 numeric values, which represent the state's population from 1770 through 1990, in 10-year increments. The next tab separator is followed by a single numeric value, which specifies the state's area in square miles.

The data file cannot contain blank lines or comments. Missing or extra data on a line causes an error.

**Note:** One tab (the default separator) separates each field. Do not insert multiple tabs to line up the fields visually; this generates blank fields. The order of the columns must match the format specified by the configuration file.

Any field in the data can also be a "?", indicating that the data is null (unknown). See Appendix J, "Nulls in MineSet."

## Data Types

The Map Visualizer supports integer, floating point number, and string data types, as well as arrays of these types. The following data types are supported:

- **int** represents a 32-bit signed integer.
- **float** represents a single-precision floating point number. The decimal point is optional. Numbers in exponential "e" notation are also accepted.
- **double** represents a double-precision floating point number. The decimal point is optional when representing a floating point number. Numbers in exponential "e" notation are also accepted. The superior precision of **double** can be useful for accurately representing large numbers, since **float** can represent only seven or eight significant digits accurately. This superior accuracy, however, consumes twice the memory space of **float**.

- **dataString** represents a string that is unlikely to appear multiple times. If it appears multiple times, multiple copies are made.
- **string** represents a string of characters that can appear multiple times in the data file. Unlike a **dataString**, only a single copy of a given string is stored in memory, no matter how many times it appears in the data. This saves memory for strings appearing many times.

  Comparing **strings** is also much quicker than comparing **dataString**s. Processing is somewhat slower when looking for duplicate strings as they are read in. An example of **string** use is for a division name that appears once for each department in the division. If you are unsure whether to use a **string** or a **dataString**, use a **string**.
- **fixed string** represents a string of fixed length. Like a **dataString**, if a **fixed string** appears multiple times, multiple copies are made. In general, **fixed strings** are used internally for representations of data from data bases, and are generally better to use than **strings** or **dataStrings**.
- **date** represents a date and time. In the data file, **date** must appear in the format MM/DD/YY HH:MM:SS.

## Fixed Arrays

With the Map Visualizer, you can use one- or two-dimensional arrays of fixed size. In a fixed-sized array, all entries of the given type have the same number of values. Arrays contain the data values across one or two independent variables, that is, those dimensions controlled by the sliders.

A variant of the “enumerated array” is the “null enumerated array.” This is a variant of the enumerated array with an additional entry at the beginning for null, which is represented by “?”. See “Enumerated Arrays” in Appendix B for a discussion of enumerated arrays.

# The Configuration File

The configuration file format is flexible. Words in it must be separated by spaces, and it is case-sensitive. Except for the include statement and text within quoted strings, spacing and line breaks are irrelevant.

## Overview

The configuration file's structure and grammar are explained in the following sections.

### Sections

The configuration file consists of a series of sections, each of which has the following syntax:

*sectionKeyword*

```
{
   statements...
}
```

where *sectionKeyword* names the section. A semicolon (;) can follow the closing brace (}) but is not required. The order of the sections is significant, since sections can refer to variables defined in previous sections.

### Defaults Files

As each section is encountered, a special configuration file (referred to as a *defaults file*) is also read in. The defaults file has the same name as the section. Defaults files contain options statements. These files are searched in the following order, as specified by the X-resource *Mapviz*configPath* in the file */usr/lib/X11/app-defaults/Mapviz*.

1. The directory */usr/lib/MineSet/mapviz*. This directory contains system defaults.
2. The *~/.MineSet* directory (where the tilde, ~, indicates your home directory). You can set up personal defaults in this directory.
3. The current directory. This lets you set up defaults for each directory.

Files with the same name can appear in more than one of the above-named directories; in this case, the order given is the one in which the directories are read. If the same option is found in multiple files, the last option read is used. Note that the appropriate section in the configuration file is read after all the defaults files; thus, options in the configuration file override those in the defaults files.

### Statements

A statement has the following syntax:

*statementKeyword info* `;`

where *statementKeyword* defines the statement, and *info* varies according to the keyword. A statement can be another section (using the brace format defined under "Sections" on page 576).

### Variable Names

A variable name can appear in two formats:

- In the first format, it is a letter followed by a number of letters, digits, or underscores. It cannot be a keyword, and should not be placed in quotation marks.
- In the alternate form, the variable name should be surrounded by back quotes (`‘`). In this form, the variable name can match a keyword, and can contain even non-alphanumeric characters. The primary purpose of this second form is for configuration files generated automatically by the Tool Manager.

There is no scoping of variable names; a given variable name can be declared only once in the configuration file.

### Option Statements

Many sections have options statements, which have the syntax:

```
options key info, key info... ;
```

where *key* defines the specific option, and *info* depends on the key. In some cases, the *key* can be more than one word. To maximize the number of allowable variable names, most option keys are meaningful only within the appropriate option statement; keys do not conflict with variable names. You can declare several options on the same line, separating them by commas or placing them in several options statements. If two conflicting values for the same option appear, the last value is taken.

### Include Statements

The configuration file may contain lines of the form

```
include "filename"
```

These lines can appear anywhere in the configuration file, but each must be on its own line. The filename must be in quotes; anything after the closing quote is ignored. The number of nested includes is unlimited. If a relative pathname (one not beginning with a slash) is specified, the file is first sought in the directory containing the current configuration file. If include statements are present, this might not be the same as the initially loaded configuration file. If it is not found in the directory containing the current configuration file, the include file is sought in the current directory. If the file is not found, an error message appears.

### Sinclude Statements

A statement similar to an include is sinclude, which has the syntax:

```
sinclude "filename"
```

This is identical to the include statement, except that no error is given if the file does not exist; instead, the sinclude statement is ignored.

### Strings, Characters, and Comments

Strings and characters in the configuration file follow C conventions. Strings are in double quotation marks (“), and characters are in single quotation marks (’). All standard backslash conventions are followed (for example, `\n` represents a new line).

Comments begin with a pound (#) symbol at the beginning of a line; anything after this symbol to the end of the line is ignored.

## Keywords

The currently recognized keywords are listed below. Variables can not have these names unless they are surrounded by back quotes (‘). Tokens appearing only in option statements are not keywords, and can be used for variable names.

**Table C-1** Keywords for the Map Visualizer

| | | | |
|---|---|---|---|
| buckets | expressions | level | outlines |
| color | file | map | scale |
| colors | float | message | separator |
| datapoints | from | modulus | slider |
| dataString | height | monitor | string |
| date | input | null | summary |
| divide | int | objects | title |
| double | key | off | to |
| enum | label | on | view |
| execute | legend | options | |

## Expressions

Expressions are accepted in several places in the input. Expressions follow standard C-language syntax The operations and their expressions are listed in Table C-2:

**Table C-2** Operators Used With Expressions

| Operator | Description |
|---|---|
| + | Addition |
| - | Subtraction |
| * | Multiplication |
| / | Division |
| % | Modulus |
| == | Equals |
| != | Not equals |
| > | Greater than |
| < | Less than |
| >= | Greater than or equal to |
| <= | Less than or equal to |
| && | AND |
| \|\| | OR |
| ! | NOT |
| & | Bitwise AND |
| \| | Bitwise OR |
| ^ | Bitwise XOR |
| A?B:C | If (A), then B else C |

Also, the following functions are available:

- **divide**(x, y, z) divides *x* by *y*, unless *y* is zero. If *y* is zero, the result is *z*; this is equivalent to y==0 ? z : x/y.
- **modulus**(x, y, z) is similar to **divide**, but for modulus.

Type handling is similar to that in C. Expressions using **int** and **float** promote both sides to float. Expressions using **int** and **double**, or **float** and **double** promote both sides to double. The result of a relational expression (for example, ==, <) is always an **int**. Type casting is also supported.

Unlike in C, strings can be compared using relational expressions; the strings are compared lexicographically.

The following sections explain the use and syntax of the Map Visualizer configuration file's input, expression, and view geography sections.

## The Input Section

The first section of a data file is normally the **input** section. It defines the name and format of the data file. A typical input section might look like this:

```
input
   {
   file
      "/usr/lib/MineSet/mapviz/examples/population.usa.data";
   enum int Year from 1770 to 1990 by 10;
   string states;
   float population[enum Year] separator ' ';
   float sqMiles;
   }
```

This example specifies that the input data file is called *population.usa.data*, and that there are three tab-separated (the default) fields as follows:

- one of type **string**
- one a fixed-length vector of type **float**, with each value separated by a space
- one a scalar value of type **float**

When the input section is entered, the defaults file, */usr/lib/MineSet/mapviz/input.mapviz.options,* is read in.

### File Statements

The **file** statement names the data file to be read. This statement is required. Its syntax is

```
file "filename";
```

The file name must be in double quotation marks. If it is a relative pathname (no leading slash), it is first sought in the directory containing the current configuration file. If include statements are present, this might not be the same as the initially loaded configuration file. If it is not found in the current configuration file's directory, the file is sought in the current directory.

### Enum Statements

Enum statements declare enumeration variables that index into array fields. The enum statement has three forms.

- The first form is

  ```
  enum type name from value1 to value2 by increment;
  ```

  This declares an enum with values starting at *value1* and incremented by *increment* until they reach or exceed *value2*. For example, the statement:

  ```
  enum int age from 20 to 70 by 10;
  ```

  declares age as an array dimension with the values 20, 30, 40, 50, 60, and 70.

*Type* must be a number type (**int**, **float**, or **double**) or **date** (see "Dates" on page 583).

- The second enum statement form is

  ```
  enum type name from value1 to value2 across numberOfValues;
  ```

  This declares an enum with values ranging from *value1* to *value2*. The *numberOfValues* is an integer specifying the number of values. For example, the statement

  ```
  enum int age from 20 to 70 across 6;
  ```

  declares age as an enum with the values 20, 30, 40, 50, 60, and 70.

  *Type* must be a number type (**int**, **float**, or **double**) or **date** (see "Dates" on page 583).

- The third enum statement explicitly lists the enumeration values. Its form is

  ```
  enum type name { value1, value2, ..., valueN };
  ```

  *Type* can be any type or date (see "Dates" on page 583).

### Dates

The enum statement includes special support for a date type that handles date and time values starting Jan 1, 1753. The date type is valid only within enum statements. A date enum statement can have the following syntaxes:

```
enum date “format” name from “value1” to “value2” across
        numberOfValues;
enum date “format” name { value1, value2, ..., valueN };
enum date “format” name from “value1” to “value2” by
        “increment”;
```

The *format* string specifies the format of the values; it is useful for controlling how dates are displayed in the animation control panel. The syntax of the *format* string is similar to the scanf function in C. Various units of time are represented by special characters preceded by the percent symbol (%). For example:

```
enum date cq “Calendar Q%Q, %Y” from “Calendar Q1, 1980” to “Calendar
Q3, 1985” by “1 quarter”;
```

The “Calendar Q” in the *format* string matches the “Calendar Q” in *value1* and *value2*. The %Q in the *format* string indicates that the next number in *value1* and *value2* is the calendar quarter. The comma and space in the *format* string match the commas and spaces in the values. Finally, the %Y in the *format* string specifies that the year values are next.

Table C-3 lists the characters that can follow the percent symbol and the units of time they represent.

**Table C-3** Characters That Can Follow the Percent Symbol in the Format String

| Character | Time Unit | Precision |
|---|---|---|
| Y | year | 4 |
| Q | calendar quarter | 1 |
| M | month | 2 |
| N | month name | >= 3 |
| D | day | 2 |
| h | hour | 2 |
| m | minute | 2 |
| s | second | 2 |

With the exception of N, each character matches an integer of the specified precision. N matches 3 or more characters giving the English name of the month.

The from-to-by form of the enum statement includes an increment value. For dates, the increment is a quoted string containing an integer, an optional space, and one of the special characters in Table C-3 or one of the symbols **year**, **quarter**, **month**, **day**, **hour**, **minute**, and **second**. The plural forms of these symbols are also accepted. Note that these symbols are not keywords, since they have special meaning only in the increment string. The following are examples of valid increments:

```
“1 year”
“7 days”
“4h”
```

### Data Statements

The data statements declare the columns in the data file. The columns must be declared in the order they appear in the data file. The format of most data statements is

```
type name;
```

where *type* is **int**, **float**, **double string**, **dataString**, **date**, and **fixedString(*n*)**, where *n* is an integer representing the width of the string; *name* is the variable name. Unlike in C, only one variable can be declared per statement.

### Fixed Arrays

Fixed arrays can also be declared using simple numeric data declarations; however, if you also are going to declare a slider, you must use the enum declaration form. The declaration syntax is

```
type name [ number ] ;
```

For example:

```
float revenue [50];
```

You can also override the separator by declaring it as

```
type name [ number ] separator ’char’;
```

For example:

```
float revenue [50] separator ’:’;
```

If no separator is specified, the default separator (usually a tab) is used.

Fixed arrays can also be two-dimensional, such as

```
enum string products {“bread”,“milk”,”cheese”,”cereal”,
”apples”,”lettuce”,”juice”,”toothpaste”,”soap”,”eggs”};
```

```
enum year from 1985 to 1994 by 1;
```

```
float prices[enum products][enum year];
```

or

```
float prices[10][20];
```

which might be used for an array of prices for a set of 10 products over a 20-year period.

Using the *prices* array, for example, if you specified in the Tool Manager that data was to be retrieved from the database in "wide" mode (with a bin for null values), the enumerated *products* are declared as:

```
float prices[null enum products][enum year];
```

and the first column contains the prices for unknown products (products not in the enumerated list of ten known products) declared in the *enum string products* statement.

### Input options

The input section of a data file has several options. All **options** statements begin with the word “options” and have one or more comma-separated options.

- The separator option defines the separator between columns in the data file. The default separator is a tab. The syntax is

  ```
  options separator ’char’;
  ```

  For example:

  ```
  options separator ’:’;
  ```

  **Note:** Arrays can override the separator.

- The monitor option allows a dynamic update of the data displayed. When the specified file is changed (for example, through the UNIX *touch* command), the data file (not the configuration file) is reread. Note that although the data file could be used to trigger the updates, it is better to use a different file so that the data file is not read while it is being updated. The syntax of the monitor option is:

  ```
  options monitor "filename";
  options monitor "filename" timeout;
  ```

where *filename* is the file to watch, and the optional *timeout* specifies the number of seconds to wait after the file changes. If the user interacts with the application in any way during this timeout (via the mouse or keyboard), the timeout restarts. Updating the file can take a few seconds. By specifying a timeout, the chances of an update occurring while the user is interacting with the tool are minimized. This might delay the update. If no timeout is specified, the update occurs immediately.

The file being monitored must exist at the start of the program. When this file is being updated, it must not be removed and re-created; instead, only its modify time should be updated (for example, through the *touch* command). If the file is deleted, subsequent updates are not shown.

Suppose a program extractor extracts data from a database into a data file. If you want the program to update the data file every 10 minutes, the script you write might look like this:

```
extractor > dataFile;           # create first data file
touch trigger;                  # create the trigger file
while (sleep 600)               # sleep 10 minutes
do
extractor > dataFile;           # create new data file
touch trigger;                  # force a reread
done &                          # this loop goes in the
                                # background
mapviz configFile;              # run mapviz
kill $!                         # when mapviz exits, kill
                                # the update loop
```

The monitor option can be used only if the file alteration monitor */usr/etc/fam* is installed (this can be found in the subsystem *desktop_eoe.sw.fam*).

The input section of configuration file might look like this:

```
input
{
   file "dataFile:
   #data declarations here
   options monitor "trigger" 15;
}
```

- The backslash option controls whether backslashes in the input data are treated specially or like other characters. The syntax is:

```
 options backslash off;
 options backslash on;
```

The default is off. If backslash processing is on, separators in the input data preceded by backslashes are treated as regular characters rather than separators. Also, within strings standard C-style backslash processing is done.

## The Expressions Section

The expressions section pf a data file lets you define additional columns that are expressions of existing columns. For example, one column can be defined as the sum of two other columns. The following is a sample expression section. This section assumes two existing fixed-length columns of type **double**: “male” and “female”; these represent spending by males and females on various goods across time (one independent dimension). Two columns are added: “total” represents the total dollars spent, and “pctFemale” represents the percentage of dollars spent by females.

```
expressions
{
double total[enum month] = male+female;
double pctFemale[enum month] = divide(female*100,total,50.0);
}
```

**Note:** The pctFemale calculation uses “total,” defined in the previous section. Also, note the use of the divide function rather than the **/** operator. This results in 50% for the case where there are no dollars spent at all; using the **/** operator generates a divide by zero error in such a case. (The divide function is described in the “Expressions” section.)

The format of the expressions section is

```
expressions
{
   expressionDeclaration;
   ...
}
```

where *expressionDeclaration* has the following syntax:

```
type name = expression ;
```

The format of *expression* has already been described.

Since the expressions section has no options, no defaults file is read in for it.

## The View Section

The view section of a data file describes how the graphic objects are displayed, including the mapping of heights, colors, labels, and so forth. A sample view section is

```
view map
{
   map objects "usa.states.hierarchy";
   slider Year;
   height population;
   height legend label "Height: U.S. Population (1770-1990)";
   color density, scale 0 250 500 750 1000;
   color colors "white" "#ffc0c0" "#ff8080" "#ff4040" "red";
   color legend label "Color: Pop. Density" "0/sq-mile"
            "250/sq-mile" "500/sq-mile" "750/sq-mile"
            "1000/sq-mile";
   message "population %,.0f   %,.1f per sq mile",
   population, density;
   execute "xconfirm -t 'Population %,.0f'
                     -t 'averaging %,.1f per sq mile'
                     -t 'across %,.0f sq-miles' > /dev/null",
        population, density, sqMiles;
   }
```

The first words of the view section (before the opening brace) describe the type of view. The only view type supported is **view map**; thus, these words must introduce the view section.

When entering the view section, the *viewMap.mapviz.options* defaults file is read in. Note that there is no simple view defaults file, so the full name *viewMap.mapviz.options* must be used.

### Title Statement

The **title** statement inserts a title string at the bottom of the main window. The syntax is

```
title string;
```

where *string* is a string enclosed by double- quotation makes.

### Map Statement

The map statement specifies how the graphical objects are to be drawn in the main window. The map statement has three possible syntaxes: one required, the other two optional. The required syntax is

```
map objects hierarchy_filename;
```

where "objects" is a keyword, and *hierarchy_filename* is a filename enclosed in double quotation marks. This statement names the *.hierarchy* file describing the 3D graphical objects that exhibit heights and colors.

The following **map** statements are optional:

- `map outlines` *hierarchy_filename*`;`

  Declares graphical objects that are drawn as flat lines on which the **map objects** objects are placed. See the samples provided in *examples/population.usa.cities.mapviz*.

- `map level` *column_name*`;`

  Specifies an alternative level of the geographical hierarchy for initial display. For example, in the *examples/population.usa.mapviz* file, the unstated default is

  ```
  map level states;
  ```

  and the main window initially displays individual states. If, instead, the configuration file specified

  ```
  map level eastWest;
  ```

  the main window initially displays the United States as two halves: East and West.

### Slider Statement

The **slider** statement identifies a key to be used as a slider dimension. Its syntax is

```
slider [enum] enumName;
```

where *enumName* is the name of an enum variable declared in the input section. Note that the **enum** keyword is optional.

There can be 0, 1, or 2 slider statements. The first slider statement applies to the horizontal slider. The second slider statement applies to the vertical slider. If there is no slider statement, the resulting display does not include animation.

No slider statement is required if “height” and “color” map to non-array variables. One slider statement can be included if “height” and “color” map to one-dimensional arrays. Two slider statements can be included if “height” and “color” map to:

- two-dimensional arrays, or
- one-dimensional arrays, where dimensions are enum variable names that one of the sliders controls.

### Height Statement

The **height** statement describes how the columns of data are mapped to the height of objects. It consists of a series of clauses separated by commas. The first clause normally contains the name of a column to be mapped to height (“population,” in the example in the section “The View Section” on page 588). The column must be of a number type (**int**, **float**, or **double**), of which **float** is the most memory-efficient. If the column is a fixed-length array, the **view** section also must contain at least one, and no more than two, **slider** statements.

If no height column is specified, all bars are flat, and the remaining height clauses have no effect.

The **scale** clause lets you scale the height values. Normally, the height variable is mapped directly to the height of the graphical objects, so that the tallest object (with the largest numeric value) rises towards the top of the view window. With the optional scale clause, all values are multiplied by the scale. The scale clause syntax is

```
scale float
```

The **legend** clause defines the meaning of the height mappings. Any string can be placed in the height legend. The legend clause has the following syntaxes:

legend off — This turns off the height legend (this is the default).

legend on — This turns on the height legend. The legend can be changed by using the legend label form, in which case **legend on** is unnecessary. The legend’s default syntax is

`height:`*`varname`*

where *varname* is the name of the variable that is mapped to height.

legend label *string*

where *string* is the name of the variable that is mapped to height. The legend can be changed by using the legend label form. If **legend label** is used, **legend on** is unnecessary.

### Color Statement

The color statement describes how values are mapped to colors. The format is similar to that of the height statement, consisting of several clauses that can be separated by commas or entered as multiple statements.

**Color naming** follows the conventions of the X Window System, except that the names must be in quotation marks. Examples of valid colors are “green,” “Hot Pink,” and “#77ff42.” The last one is in the form “#*rrggbb*”, in which the red, green, and blue components of the color are specified as hexadecimal values. Pure saturation is represented by ff, a lack of color by 00. For example, “#000000” is black, “#ffffff” is white, “#ff0000” is red, and “#00ffff” is cyan.)

**The color variable** lets you specify a single column to be mapped to a color (as with height). The column must be a number type.

**The colors clause** specifies the colors to be used. The colors clause’s syntax is

```
colors "colorname" "colorname"...
```

The format for *colorname* is described above. Note that there are no commas between the colors. This is because commas are used to separate clauses in the color statement. A sample colors clause is

```
colors "red" "gray" "blue"
```

Colors in the list are subsequently referred to by their index, starting at zero. In the above example, red is color 0, gray is color 1, and blue is color 2.

If there is no colors statement, colors are chosen randomly; however, if there is a colors statement, at least as many colors must be specified as are to be mapped.

**The scale clause** allows assignment of values to a continuous range of colors. For example, when displaying a percentage, red can be assigned to 0%, gray to 50%, and blue to 100%. Intermediate values are interpolated; for example 25% is pinkish, and 55% is a slightly bluish gray.

The syntax for the scale clause is

```
scale float float ...
```

The first value is mapped to color 0, the second to color 1, and so forth. The colors statement must contain at least as many colors as are to be mapped to the largest index.

Values in this statement must be in increasing order. Any value less than the first color is assigned the value of the first color. Any value greater than the last value is assigned the last color. Intermediate values are interpolated.

For example, assume the pctFemale column indicates what percentage of the group is female, and you want to map a group that is 100% female to red, 100% male to blue, and 50% each to gray. The colors statement for this is:

```
colors pctFemale, colors "blue" "gray" "red", scale 0 50 100;
```

**The buckets clause** is similar to the scale clause without interpolation. All values are rounded down to the highest value in the clause, and that exact color is used. Values less than the first value use the first color.

The syntax for the buckets clause is

```
buckets float float ...
```

The syntax and assignment of colors is the same as for the scale clause.

If, in the pctFemale example, you used the buckets clause instead of the scale clause, the statement would be:

```
colors pctFemale, colors "blue" "gray" "red", buckets 0 50 100;
```

All values greater or equal to 100 are colored red. Values greater than or equal to 50, but less than 100, are gray. All other values are blue.

**The normalize clause controls a form of color normalization, analogous to height normalization. By default, color normalization is off. The syntax is**

```
normalize off;
normalize on;
```

When color normalization is on, the color scale (or buckets) list of values must range between 0 and 100. These color values then represent relative percentages of the range from the minimum to the maximum for a given viewed scene. For example,

```
color totalSales;legend off
color scale 0 100, colors “white” “red”, normalize on;
```

generates colors in the range of “white” to “red,” where “white” corresponds to the minimum “totalSales” and “red” corresponds to the maximum “totalSales” for the particular set of graphical objects being viewed. See */usr/lib/MineSet/mapviz/examples/variations.articles.france.mapviz* for a more elaborate example.

The **legend** clause creates a legend of the colors. By default, the color legend is off. The legend clause syntax can be any of the following:

```
legend off
legend on
legend "string" "string" ...
legend label "string"
legend "string" "string" ... label "string"
```

The **legend off** clause turns the legend off. The **legend on** clause turns the legend on. It can be omitted if other legend statements are included. Specifying only **legend on** generates the default legend.

The default legend includes a single label to the left (with the name of the column that is mapped to color), and a list of colored labels on the right (with values obtained from the scale clause, the buckets clause, or from the keys). To override the strings in the colored labels, specify the strings as:

```
legend "string" "string
```

To override the label on the left, specify it following the word label. To eliminate this label, specify an empty string; that is

```
legend ""
```

### Message Statement

The **message** statement specifies the message displayed when an object is selected. The syntax is similar to the C **printf** statement. A sample message statement is

```
message "%s: $%f, %.0f%% of target, %.0f%% of last year",
      product, sales, pctTarget, pctLastYear;
```

This could produce the following message:

```
furniture: $2425.37, 23% of target, 87% of last year
```

The formats must match the type of data being used:

- Strings must use %s.
- Ints must use integer formats (such as %d).
- Floats and doubles must use floating point formats (such as %f).

For details of the **printf** format, see the printf (1) reference (man) page (type **`man printf`** at the shell prompt).

A special format type has been added to **printf**. If the percent sign is followed by a comma (for example, “%,f”), commas are inserted in the number for clarity. Currently, only the United States convention of d,ddd,ddd.dddd is supported, with the decimal point represented by a period, and commas separating every three places to the left of the decimal point. For example, if the above format were:

```
message "%s: $%,f, %,.0f%% of target, %,.0f%% of last year",
         product, sales, pctTarget, pctLastYear;
```

it would produce the message:

```
furniture: $2,425.37, 23% of target, 87% of last year
```

The $, *, h, l, ll, L, and n **printf** format options are not supported.

All values, including the format string, are expressions. Thus, if you had a pctFemale column, but wanted a more gender-neutral message, you can use:

```
message pctFemale>50?"%f%% females":"%f%% males",
         pctFemale>50?pctFemale:100-pctFemale;
```

If pctFemale is 70, the message “70% females” is displayed; if pctFemale is 30, the message “70% males” is displayed. In this case, you can also achieve the same result with a single format string:

```
message "%f%% %s", pctFemale>50?pctFemale:100-pctFemale,
         pctFemale>50?"females":"males";
```

If no message is specified, a default message containing the names and values of all the columns is used.

### Execute Statement

The **execute** statement lets you execute a shell command by double-clicking an object. The syntax is similar to that of the *message* command.

Here is a sample execute statement that uses *xconfirm* to show a window with information about the item. Note that the command line (string) is shown as three lines. In an actual file, this should be on a single line. Multi-line strings are not supported.

```
execute "xconfirm -t '%s' -t 'population %,.0f' -t '%,.0f per
    sq mile' -t '%,.0f sq-miles' > /dev/null", states,
    population, density, sqMiles;
```

This might produce a dialog with the message:

```
CA
64 per sq mile
266,807 sq-miles
```

If there is no execute statement, double-clicking an object has the same effect as single-clicking it.

### Summary Statement

The **summary** statement specifies the initial setting of the Show Data Points pulldown menu option. The syntax is

```
summary datapoints on;
```

or

```
summary datapoints off;
```

The **summary** statement is optional, and the default setting is *off*.

## The Hierarchy File

The hierarchy file defines the object hierarchy, allowing objects to be displayed at different levels of aggregation. It enables the drill up and drill down capabilities of the Map Visualizer (see “File Requirements” in Chapter 6). The hierarchy file is specified in the *.mapviz* configuration file with the `map object` *`hierarchy_filename`* statement (see “The View Section” on page 588 and “Map Statement” on page 589).

Here are the first few lines of the *usa.states.hierarchy* file:

```
states        regions        eastWest        USA
usa.states.gfx        usa.states.gfx
     usa.states.gfx        usa.states.gfx
AL        E_S_CENTRAL        USA_E        USA_ALL
AR        W_S_CENTRAL        USA_W        USA_ALL
AZ        MOUNTAIN        USA_W        USA_ALL
CA        PACIFIC        USA_W        USA_ALL
CO        MOUNTAIN        USA_W        USA_ALL
CT        NEW_ENGLAND        USA_E        USA_ALL
DE        MID_ATLANTIC        USA_E        USA_ALL
```

This defines how states combine into regions, sectors, and into a single object encompassing all states.

The first record is a list of column names of the hierarchy; each name must be separated by a single tab ('\t') character. One of the column names must match a type **string** column in the **data file**, as declared in the configuration file's **input** section in "The Input Section" on page 581. In this example, the first column name, *states*, is also the name of a data column in the example *population.usa.mapviz*. The number of column names in this record must be the same as the number of columns of hierarchy data, beginning at the third record of the *.hierarchy* file. If there is only one column name (for example, *gfx_files/canada.provinces.hierarchy*), then there are only two records in the *.hierarchy* file.

The second record is a list of *.gfx* file pathnames, where each pathname is separated by a single tab ('\t') character. Each column name in the first record must have a matching *.gfx* file pathname.

If there is a single column name (and *.gfx* file pathname), then only these two records must be in the file. If there are multiple column names and pathnames, then starting at the third record in the *.hierarchy* file is an N-column table of keywords of graphical objects, where N is the number of column names in the first record. Looking at the sample file, the first column contains "states" keywords, the second column "regions" keywords, the third the "eastWest" keywords, and the fourth the "USA" keyword. The matching *.gfx* files contain the positions and shapes of each of the column's graphical objects.

The third and remaining records in the hierarchy file are the hierarchy data. These records define how objects at one level correspond to objects at other levels.

## The *.gfx* File

The .gfx files define the geometry of each object used by the Map Visualizer when displaying the objects. Each *.gfx* file contains multiple records, one for each object being displayed. Each record contains:

- the gfx keyword name
- the gfx full name
- the vertex pair count
- the shape hint
- the vertex pairs

The following steps guide you through the procedure for building *.gfx* files.

1. Using a digitizing scanner, convert a geographical image into an RGB image file format. Note that the image itself is not used by the Map Visualizer; it is just used as a template for defining the graphical objects in Step 6 on page 597.
2. Launch the i3dm application in */usr/demos/bin/*. (If this application is not currently installed, it can be installed from the IRIX™ 5.3 or 6.2 distribution, in the subsystem demos.sw.tools.) This creates windows on your screen: a Menu window on the left, an Input window across the bottom, and four windows (labeled *TOP*, *Pers*, *Front*, and *Right*) on the right. All *i3dm* windows must remain displayed (not iconified) for i3dm to work.
3. Move the cursor to the Front window.
4. Press the right mouse button to display options. Continue holding the right mouse button, and scroll to the Image Background option, then to the Load Image option. The Input window (at the bottom of your screen) prompts you for a name to apply to this image.
5. Enter the name of the RGB image file. The image appears in the Front window.
6. Delineate the shape of each object in the image by pointing and clicking at significant points on the boundary of each object. Do this in a clockwise sequence for each object. Each identified point is called a "vertex" and is represented by numeric x- and y-axis values. These values are assigned by the i3dm application and exist in a relative frame of reference for that RGB image file. The following procedure is used to delineate each object's shape:
   - Use the middle mouse button to drag the image in the Front window so that the object you are going to delineate is completely exposed. If this is not possible, see step 8.
   - Go to the Menu window, and click the right mouse button on the Create pulldown menu.
   - Choose the Line option.
   - Start the point-and-click process of selecting vertices with the left mouse button in the Front window. Note that the greater the number of vertices you identify, the more accurate the resulting graphical image is.
   - Note the red line crosshairs as you move the cursor over the image. As you click the left mouse button to declare each vertex, a small red box appears at that point. The box of the previous vertex changes to a small "x," and a yellow line connects the new vertex to the previous vertices. As you move clockwise around the object, stop selecting vertices immediately before you are about to close the shape (that is, before clicking on the first vertex you selected when starting to delineate the object).

- Go to the Menu window, and click the right mouse button on the Attrib pulldown menu.
- Scroll to the Name option. The Input window (at the bottom of your screen) prompts you for a name.
- Enter a unique identifier for the object you have just delineated. Do not use spaces. The becomes the object's gfx keyword name. For example, in *population.usa.mapviz* the gfx column is specified as the first column in the data file. This first column contains strings such as "CA" and "NY." These are the keyword names for the states. These keyword names are the gfx keyword names in the associated gfx file.
- Go to the Menu window, and click the right mouse button on *Done*.

7. Repeat Step 6 for every other object in the same image. If the object adjoins a previously identified object, you must reuse common vertices by selecting them with the middle mouse button instead of the left mouse button. Using the middle mouse button while the crosshairs are positioned close to a previously selected vertex ensures that the newly selected vertex is identical to the previously selected one.

   **Caution:** If a graphical object is too large to fit into the Front window, you must identify the vertices in sections. After all the objects are declared and the vertex information written to an ASCII file, you must edit this output file to join the sections of each subdivided object.

8. When all objects are identified, save the recorded vertices in a file. To do this:
   - Go to the Menu window and press the right mouse button on the File pulldown menu.
   - Scroll down to the File i3dm format option and choose it. The Input window (at the bottom of your screen) prompts you for a filename.
   - Enter a filename, specifying the *.i3dm* suffix.
9. Exit the i3dm application. To do this
   - Go to the Menu window, and choose the *File* pulldown menu.
   - Scroll to the Exit option, and choose it.
10. Convert the i3dm format file into a gfx file format by using the convert.i3dm utility, using the following syntax:

    ```
    /usr/lib/MineSet/mapviz/convert.i3dm inputFilename
    outputFilename.gfx
    ```

For each object, the utility prompts you to

- confirm the object’s keyword name (which defaults to the Attrib name you supplied in Step 6, substep 6, above, when identifying the vertices)
- declare the object’s full name (which is the name the user sees in the Map Visualizer’s Selection window when using the mouse to select a geographical object)
- declare if the object has a concave shape that requires special handling

**Note:** Declaring an object to be concave results in an accurate graphical display, but at the cost of slower performance. One strategy is to declare no objects as concave, examine the display to determine which objects are inaccurately drawn, then manually edit the gfx files for those objects, changing the string “convex” to “concave.” Another strategy is to declare all objects as “concave” (assuming there are few objects), then determine if the resulting performance is acceptable.

# Creating Data and Configuration Files for the Scatter Visualizer

The first part of this appendix describes the types and formats of data supported by the Scatter Visualizer. Data input to the Scatter Visualizer must be provided as a single file containing raw data, usually in a tab-separated ASCII text form.

The second part discusses the configuration file, which describes how the Scatter Visualizer reads in, and displays, the data file.

Both the data and configuration files can be generated automatically by the Tool Manager (see Chapter 3).

**Note:** Read Chapter 7, "Using the Scatter Visualizer," before using this appendix.

## The Data File

In its simplest form, the data file consists of a list of lines, each containing a set of fields, each separated by one tab. (Other separators are also allowed, but only one per file can separate each field. See "Input Options" on page 614.) All lines must contain the same fields. The interpretation of the fields is specified by the configuration file, described in the next section. Using the store sales data provided as part of the Scatter Visualizer package (file */usr/lib/MineSet/scatterviz/examples/store-type.data*), the first few lines of the input file appear as:

```
LIQUOR STORE    4300,4460,4800,4900,4700,4200,4250,4200
2700,2800,2750,3000,2900,2600,2500,2650
1600,1650,1900,1950,2000,2200,2300,2300
GROCERY STORE    700,900,600,800,877,755,800,600
3000,2900,3100,2800,2899,2950,3400,3300
10000,11000,9000,9800,9700,9650,9770,9700
```

In this sample file listing, each line consists of four fields, separated by tabs. The first field is a string that identifies a store type. The second field is an array of eight numbers, separated by commas, which might be sales of alcohol over an eight-day period. The third and fourth fields are also arrays of eight numbers that could represent sales of tobacco and food, respectively, over the same eight-day period.

The sample data file has other fields in the same format, but these are not shown. These additional fields correspond to sales of other products (see the configuration file */usr/lib/MineSet/scatterviz/examples/store-type.scatterviz* for a listing of all the fields).

The data file cannot contain blank lines or comments. Missing or extra data on a line causes an error.

**Note:** One tab (the default separator) separates each field. Do not insert multiple tabs to line up the fields visually; this generates blank fields. The order of the fields must match the format specified by the configuration file.

## Data Types

The Scatter Visualizer supports integer, floating-point number, and string data types, as well as arrays of these types. The following data types are supported:

- **int** represents a 32-bit signed integer.
- **float** represents a single-precision floating point number. The decimal point is optional. Numbers in exponential "e" notation are also accepted.
- **double** represents a double-precision floating point number. The decimal point is optional when representing a floating point number. Numbers in exponential "e" notation are also accepted. The superior precision of **double** can be useful for accurately representing large numbers, since **float** can represent only seven or eight significant digits accurately. This superior accuracy, however, consumes twice the memory space of **float**.

- **dataString** represents a string that is unlikely to appear multiple times. If it appears multiple times, several copies are made. A **dataString** is typically used to store an memory address. Addresses are unlikely to be compared, and each record can have a different address.
- **string** represents a string of characters that can appear multiple times in the data file. Unlike a **dataString**, only a single copy of a given string is stored in memory, no matter how many times it appears in the data. This saves much memory for strings appearing many times.

  Comparing **strings** is also much quicker than comparing **dataString**s. Processing is somewhat slower when looking for duplicate strings as they are read in. An example of **string** use is for a division name that appears once for each department in the division. If you are unsure whether to use a **string** or a **dataString**, use a **string**.
- **fixed string** represents a string of fixed length. Like a **dataString**, if a **fixed string** appears multiple times, multiple copies are made. In general, **fixed strings** are used internally for representations of data from data bases, and are generally better to use than **strings** or **dataStrings**.
- **date** represents a date and time. In the data file, **date** must appear as in the format MM/DD/YY HH:MM:SS.

## Arrays

With the Scatter Visualizer, you can use fields that are one- or two-dimensional arrays of fixed size. In a fixed-sized array field, all entries of the given field are arrays with the same number of values. Arrays contain the data values across one or two independent variables (those dimensions controlled by the sliders). In the listing from the file *store-type.data*, the second, third, and fourth fields are arrays.

## Null Values

Any field or array element in the data file can also have the value “?” (question mark), indicating an unknown or null value (see the discussion of nulls in Appendix J).

## The Configuration File

The configuration file format is flexible. Words in it must be separated by spaces, and it is case-sensitive. Except for the include statement and text within quoted strings, spacing and line breaks are irrelevant.

### Sections

The configuration file consists of a series of sections, each of which has the form:

*sectionKeyword*
```
{
statements...
}
```

where *sectionKeyword* names the section. The order of the sections is significant, since sections can refer to variables defined in previous sections.

### Defaults Files

As each section is encountered, a special configuration file (referred to as a *defaults file*) is also read in. Defaults files normally contain options statements. These files are read in the following order:

1. The directory */usr/lib/MineSet/scatterviz*. This directory usually contains system defaults.
2. The *~/.MineSet* directory (where the tilde, ~, indicates your home directory). You can set up personal defaults in this directory.
3. The current directory. This lets you set up defaults for each directory.

Files with the same name can appear in more than one of the above-named directories; in this case, the order given is the one in which the directories are read. If the same option is found in multiple files, the last option read is used. Note that the appropriate section in the configuration file is read after all the defaults files; thus, options in the configuration file override those in the defaults files.

### Statements

A statement has the following form:

```
statementKeyword info ;
```

where *statementKeyword* defines the statement, and *info* varies according to the keyword.

### Variable Names

A variable name can appear in two formats:

- In the first format, it is a letter followed by a number of letters, digits, or underscores. It cannot be a keyword, and should not be quoted.
- In the alternate form, the variable name should be surrounded by back quotes (`‘`). In this form, the variable name can match a keyword, and can contain even non-alphanumeric characters. The primary purpose of this second form is for configuration files generated automatically by the Tool Manager.

There is no scoping of variable names; a given variable name can only be declared once in the configuration file.

### Options Statements

Many sections have options statements, which have the form

```
options optionName info, optionName info... ;
```

where *optionName* defines the specific option, and *info* depends on the option. In some cases, *optionName* can be more than one word. To maximize the number of allowable variable names, most option names are meaningful only within the appropriate options statement; option names do not conflict with variable names. You can declare several options on the same line, separating them by commas or placing them in several options statements. If two conflicting values for the same option appear, the last value is taken.

## Include Statements

The configuration file can contain lines of the form

```
include "filename"
```

These lines can appear anywhere in the configuration file, but each must be on its own line. The filename must be in quotation marks; anything after the closing quote is ignored. The number of nested includes is unlimited. If a relative pathname (one not beginning with a slash) is specified, the file is first sought in the directory containing the current configuration file. If include statements are present, this might not be the same as the initially loaded configuration file. If it is not found in the directory containing current configuration file, the include file is sought in the current directory.

## Sinclude Statements

A statement similar to an include is sinclude, which has the form

```
sinclude "filename"
```

This is identical to the include statement, except that no error is given if the file does not exist; instead, the sinclude statement is ignored.

## Strings and Characters

Strings and characters in the configuration file follow C conventions. Strings are in double quotation marks ("), and characters are in single quotation marks (′). All standard backslash conventions are followed (for example, \n represents a new line).

## Comments

Comments begin with a pound (#) symbol at the beginning of a line; anything after this symbol to the end of the line is ignored, up to the end of the line.

## Keywords

The keywords recognized by the Scatter Visualizer are listed in Table D-1. Variables cannot have these names unless they are surrounded by back quotes (‘). Tokens appearing only in option statements are not keywords, and can be used for variable names.

**Table D-1** Scatter Visualizer Keywords

| | | | |
|---|---|---|---|
| across | average | axis | buckets |
| by | color | colors | dataString |
| date | divide | double | entity |
| execute | expressions | file | float |
| from | include | input | int |
| key | label | legend | max |
| message | min | modulus | monitor |
| off | on | options | scale |
| separator | sinclude | size | slider |
| string | sum | summary | time |
| to | view | | |

Currently, the keywords **execute**, **min**, **monitor**, and **time** are not used by the Scatter Visualizer.

## Expressions

Expressions are accepted in several places in the input. Expressions follow the syntax of C. The following operations and their symbols are listed in Table D-2.

**Table D-2** Operators Used With Expressions

| Operator | Description |
|---|---|
| + | Addition |
| - | Subtraction |
| * | Multiplication |
| / | Division |
| % | Modulus |
| == | Equals |
| != | Not equals |
| > | Greater than |
| < | Less than |
| >= | Greater than or equal to |
| <= | Less than or equal to |
| && | AND |
| \|\| | OR |
| ! | NOT |
| & | Bitwise AND |
| \| | Bitwise OR |
| ^ | Bitwise XOR |
| A?B:C | If (A), then B else C |

Also, the following functions are available:

- **divide**(x, y, z) divides *x* by *y*, unless *y* is zero. If *y* is zero, the result is *z*; this is equivalent to y==0 ? z : x/y.
- **modulus**(x, y, z) is similar to **divide**, but for modulus.

Type handling is similar to that in C. Expressions using **int** and **float** promote both sides to float. Expressions using **int** and **double**, or **float** and **double** promote both sides to double. The result of a relational expression (for example, ==, <) is always an **int**. Type casting is also supported.

Unlike in C, strings can be compared using relational expressions; the strings are compared lexicographically.

## The Input Section

The first section of a configuration file is normally the input section. It defines the name and format of the data file. A typical input section might look like this:

```
input  {
   file "company.data";
   string company;
   slider int income from 20000 to 60000 by 10000;
   slider date “%N %Y” purchaseDate from “Jan 1990” to “Dec
   1992” by “1 month”;
   options array separator ‘,’;
   float lifeSales[income][purchaseDate];
   float autoSales[income][purchaseDate];
   float homeSales[income][purchaseDate];
   string location;
   }
```

This example states that the input file is called *company.data*, and that there are five fields: *company*, *lifeSales*, *autoSales*, *homeSales*, and *location*. The *company* and *location* fields are of type **string**, while the other three fields are two-dimensional arrays of type **float**. Two slider dimensions are declared:

- *income*, which is of type **int**, ranges from 20000 to 60000 in increments of 10000; and
- *purchaseDate*, which is of type **date** and ranges from January 1990 to December 1992 in increments of 1 month.

The arrays *lifeSales*, *autoSales*, and *homeSales* contain values for each income and purchase date. Individual values within the arrays are separated by commas.

When the **input** section is entered, the defaults file *inputDefaults* is read in.

## File Statements

The **file** statement names the data file to be read. This statement is required. Its form is:

```
file "filename";
```

*filename* must be in double quotation marks. If it is a relative pathname (no leading slash), it is first sought in the directory containing the current configuration file. If include statements are present, this might not be the same as the initially loaded configuration file. If it is not found in the current configuration file's directory, the file is sought in the current directory.

## Enumeration Statements

Enumeration statements declare enumerations, or enums, that index into array fields. The enum statement has three forms.

- The first enum statement form is

  ```
  enum type name from value1 to value2 by increment;
  ```

  This declares an enum with values starting at *value1* and incremented by *increment* until they reach or exceed *value2*. For example, the statement

  ```
  enum int age from 20 to 70 by 10;
  ```

  declares age as an enum with the values 20, 30, 40, 50, 60, and 70.

  *Type* must be a number type (**int**, **float**, or **double**) or **date** (see "Dates" on page 611).

- The second enum statement form is

  ```
  enum type name from value1 to value2 across numberOfValues;
  ```

  This declares an enum with values ranging from *value1* to *value2*. The *numberOfValues* is an integer specifying the number of values. For example, the statement:

  ```
  enum int age from 20 to 70 across 6;
  ```

  declares age as an enum with the values 20, 30, 40, 50, 60, and 70.

  *Type* must be a number type (**int**, **float**, or **double**) or **date** (see "Dates" on page 611).

- The third enum statement explicitly lists the enum values. Its form is:

  ```
  enum type name { value1, value2, ..., valueN };
  ```

  *Type* can be any type or date (see "Dates" on page 611).

### Dates

The enum statement includes special support for a date type that handles date and time values starting Jan 1, 1753. The date type is valid only within enum statements. A date enum statement can have the following syntaxes:

```
enum date “format” name from “value1” to “value2” across
        numberOfValues;
enum date “format” name { value1, value2, ..., valueN };
enum date “format” name from “value1” to “value2” by
        “increment”;
```

The *format* string specifies the format of the values; it is useful for controlling how dates are displayed in the animation control panel. The syntax of the *format* string is similar to the **scanf** function in C. Various units of time are represented by special characters preceded by the percent symbol (%). For example,

```
enum date cq “Calendar Q%Q, %Y” from “Calendar Q1, 1980” to “Calendar
Q3, 1985” by “1 quarter”;
```

The “Calendar Q” in the *format* string matches the “Calendar Q” in *value1* and *value2*. The %Q in the *format* string indicates that the next number in *value1* and *value2* is the calendar quarter. The comma and space in the *format* string match the commas and spaces in the values. Finally, the %Y in the *format* string specifies that the year values are next.

Table D-3 lists the characters that can follow the percent symbol and the units of time they represent.

**Table D-3** Characters That Can Follow the Percent Symbol in the Format String

| Character | Time Unit | Precision |
|---|---|---|
| Y | year | 4 |
| Q | calendar quarter | 1 |
| M | month | 2 |
| N | month name | >= 3 |
| D | day | 2 |
| h | hour | 2 |
| m | minute | 2 |
| s | second | 2 |

With the exception of N, each character matches an integer of the specified precision. N matches 3 or more characters giving the English name of the month.

The from-to-by form of the enum statement includes an increment value. For dates, the increment is a quoted string containing an integer, an optional space, and one of the special characters in Table D-3 or one of the symbols **year**, **quarter**, **month**, **day**, **hour**, **minute**, and **second**. The plural forms of these symbols are also accepted. Note that these symbols are not keywords, since they have special meaning only in the increment string. The following are examples of valid increments:

```
“1 year”
“7 days”
“4h”
```

## Data Statements

The data statements declare the fields in the data file. The fields must be declared in the order they appear in the data file. The format of most data statements is

```
type name;
```

where *type* is **int**, **float**, **double string**, **dataString**, **date**, and **fixedString(*n*)**, where *n* is an integer representing the width of the string; *name* is the variable name. Unlike in C, only one variable can be declared per statement.

A data field can also be based on an enumeration. The syntax is

```
enum enumName name;
```

The field must contain **ints** corresponding to the values of the enum. For example, if the enum ageGroup is declared as

```
enum string ageGroup {"below 30", "30-39", "40-49", "50-59",
        "60 or above"};
```

the field age can be declared as

```
enum ageGroup age;
```

The field should contain **ints** between 0 and 4, where 0 is displayed as “below 30,” 1 as “30-39”, and so forth.

Only one variable can be declared per statement.

### Arrays

Arrays are also declared using data declarations. The declaration syntax for one-dimensional arrays is one of the following:

```
type name [ number ] ;
type name [ enumName ] ;
type name [ null enumName ] ;
```

For example:

```
float revenue [50];
```

The declaration syntax for two-dimensional arrays is one of the following:

```
type name [ number1 ][ number2 ] ;
type name [ enumName1 ][ enumName2 ] ;
type name [ null enumName1 ][ null enumName2 ] ;
```

For example:

```
float revenue [50][10];
```

When enums are used, the number of values in the array is taken from the declaration of the enum. For example, given the statements

```
enum int age from 20 to 70 by 10;
float clothingPurchases[age];
```

the array *clothingPurchases* must have six values, corresponding to the enum values 20, 30, 40, 50, 60, and 70.

The keyword **null** indicates an extra value at the beginning of the array, corresponding to null. Thus, the statements

```
enum int age from 20 to 70 by 10;
float clothingPurchases[null age];
```

declare *clothingPurchases* as an array with seven values: the first value corresponding to null or unknown age values, and the remaining six values corresponding to age values 20, 30, 40, 50, 60, and 70.

You can override the separator between values in an array by declaring it as:

```
type name [ number ] separator 'char';
```

For example:

```
float revenue [50][10] separator ':';
```

If no separator is specified, the default separator (usually a tab) is used.

### Input Options

All **options** statements begin with the word “options” and have one or more comma-separated options.

- The separator option defines the separator between fields in the data file. The default separator is a tab. The syntax is

  ```
  options separator ‘char’;
  ```

  For example:

  ```
  options separator ‘:’;
  ```

  **Note:** The separator is used also to separate values within arrays; however, arrays can override the separator.

- The backslash option controls whether backslashes in the input data are treated specially or like other characters. The syntax is:

  ```
  options backslash off;
  ```

  ```
  options backslash on;
  ```

  The default is off. If backslash processing is on, separators in the input data preceded by backslashes are treated as regular characters rather than separators. Within strings, this causes standard C-style backslash processing.

## The Expressions Section

The **expressions** section of a configuration file lets you define additional fields that are expressions of existing fields. For example, one field can be defined as the sum of two other fields.

The format of the expressions section is

```
expressions
{
expressionDeclaration;
...
}
```

where *expressionDeclaration* has the following form:

```
type name = expression ;
```

The following is a sample expression section. This section assumes two existing array fields of type **double**: “male” and “female”; these represent spending by males and females on various goods across time (one independent dimension). Two fields are added: “total” represents the total dollars spent, and “pctFemale” represents the percentage of dollars spent by females.

```
expressions
{
double total[36] = male+female;
double pctFemale[36] = divide (female*100, total, 50.0);
}
```

**Note:** The pctFemale calculation uses “total,” defined in the previous statement. Also, note the use of the divide function rather than the **/** operator. This results in 50% for the case where there are no dollars spent at all; using the **/** operator generates a divide by zero error.

The expressions section has no options; thus, no defaults file is read in for it.

## The View Section

The **view** section of a configuration file describes how the data is displayed, including the mapping of sizes, colors, axes, and so on. The default values for these options are in */usr/lib/MineSet/scatterviz/view.scatterviz.options*. Its form is

```
view
{
viewStatement;
...
}
```

A sample view section is

```
view {
   slider month;
   entity brand;
   axis male$, color “blue”;
   axis female$, color “red”;
   size total$, max 5;
   color pctFemale, scale 0 50 100, colors “blue” "gray"
   "red";
   message "brand %s, total sales %,.0f",brand, total$;
   }
```

When entering the view section, the *viewDefaults* file is read in.

## Slider Statement

The **slider** statement identifies an enum to be used as a slider dimension. Its syntax is one of the following:

```
slider enumName;
slider null enumName;
```

The enum name is declared in the input section. If the keyword **null** is present, the slider includes a position at the beginning corresponding to null or unknown values of the enum. Arrays indexed by the slider must be declared to match the *null* in the slider statement.

There can be 0, 1, or 2 slider statements. The first slider statement applies to the horizontal slider, the second to the vertical slider. If there is no slider statement, the resulting display does not include animation.

## Entity Statement

The **entity** statement lets you specify a variable that uniquely identifies the entities in the display. The entity statement consists of a series of clauses, separated by commas:

```
entity clause1, clause2,...
```

Alternatively, the clauses can be given in separate entity statements.

### The Entity Variable

The first clause of the **entity** statement normally contains the name of the entity variable (*brand* in the example on page 615).

### The Label Clause

This clause defines how the entities are labeled. It has the following forms:

- label off

  This turns off the labels.

- label on

  This turns on the labels. The default labels use the entity variable as the label for each entity.

- label *variable*

  This turns on the labels and uses the given variable to label the entities. When this form is used, it is not necessary to specify *label on*.

### The Label Color Clause

This clause turns on the labels and specifies their color. It has the form:

```
label color “colorname”
```

where *colorname* is the name of a color in a special format. (Color naming is explained in “Color Statement” on page 618.) The default label color is gray.

### The Legend Clause

The legend clause explains what the entities are. Any string can be placed in the entity legend. The legend clause has the following forms:

- legend off

  This turns off the entity legend.

- legend on

  This turns on the entity legend (this is the default). The default legend is

  ```
  Entity: varname
  ```

  where *varname* is the name of the entity variable.

- legend label “*string*”

  This turns the legend on and explicitly sets the legend string. If this form is used, *legend on* is unnecessary.

## Size Statement

The **size** statement describes how a field of data is mapped to the sizes of entities. The size statement consists of a series of clauses, separated by commas:

```
size clause1, clause2,...
```

Alternatively, the clauses can be given in separate size statements.

### The Size Variable

The first clause normally contains the name of a field to be mapped to size (*total$*, in the **view** example in “The View Section” on page 615). The field must be of a number type (**int**, **float**, or **double**), of which **float** is the most efficient. The field can be an array that is indexed by slider dimensions. If no size field is specified, all entities are the same size.

### The Max Clause

Normally, the size variable is mapped to the size of the entities, so that the biggest entity has a size of 5. This size can be changed by specifying a different value. If there is no size variable, the default maximum size is 2.5. The **max** clause has the form

```
max float
```

### The Scale Clause

Instead of using the **max** clause to affect size values, the **scale** clause can be used to scale these values; all values are multiplied by the scale. The scale clause's syntax is

```
scale float
```

### The Legend Clause

The **legend** clause defines the meaning of the size mappings. Any string can be placed in the size legend. The legend clause has the following forms:

- `legend off`

  This turns off the size legend.

- `legend on`

  This turns on the size legend (this is the default). The default legend is:

  `size:`*`varname`*

  where *varname* is the name of the variable that is mapped to size.

- `legend label` *"string"*

  This turns the legend on and explicitly sets the legend string. If this form is used, *legend on* is unnecessary.

## Color Statement

The **color** statement describes how values are mapped to colors. The format is similar to the size statement, consisting of several clauses that can be separated by commas, or entered as multiple statements. The syntax is:

```
color clause1, clause2,...
```

### Color Naming

Color names follow the conventions of the X window system, except that the names must be in quotes. Examples of valid colors are “green,” “Hot Pink,” and “#77ff42.” The latter is in the form “#*rrggbb*”, in which the red, green, and blue components of the color are specified in hexadecimal value. Pure saturation is represented by ff, a lack of color by 00. For example,”#000000” is black, “#ffffff” is white, “#ff0000” is red, and “#00ffff” is cyan.

### The Color Variable

As with size, you also can specify a single field to be mapped to an entity color. The field can be an array that is indexed by slider dimensions. If the field is an array, it must be a number type. If the field is a number type, the scale and buckets clauses described below can be used to map a range of colors to the values of the field. If the field is not a number type, it is sorted, and each unique value is assigned a color.

### The colors Clause

The **colors** clause specifies the colors to be used. The colors clause’s syntax is:

```
colors "colorname" "colorname"...
```

The format for *colorname* is described in “Color Naming” on page 619. Note that there are no commas between the colors, because commas are used to separate clauses in the color statement. A sample colors clause is:

```
colors "red" "gray" "blue"
```

Colors in the list are subsequently referred to by their index, starting at zero. In the above example, red is color 0, gray is color 1, and blue is color 2.

If there is no colors statement, colors are chosen randomly. If there is a colors statement, at least as many colors must be specified as are to be mapped.

### The scale Clause

The **scale** clause allows assignment of values to a continuous range of colors. For example, when displaying a percentage, red can be assigned to 0%, gray to 50%, and blue to 100%. Intermediate values are interpolated; for example 25% is pinkish, and 55% is a slightly bluish gray.

The syntax for the scale clause is

```
scale float float ...
```

The first value is mapped to color 0, the second to color 1, and so forth. The colors statement must contain at least as many colors as are to be mapped to the largest index.

Values in this statement must be in increasing order. Any value less than the first color is assigned the value of the first color. Any value greater than the last value is assigned the last color. Intermediate values are interpolated.

For example, assume the pctFemale field indicates what percentage of the group is female, and you want to map a group that is 100% female to red, 100% male to blue, and 50% each to gray. The colors statement for this is:

```
colors pctFemale, colors "blue" "gray" "red", scale 0 50 100;
```

Use the scale clause only in conjunction with a numeric color variable.

### The buckets Clause

The **buckets** clause is similar to the scale clause without interpolation. All values are rounded down to the highest value in the clause, and that exact color is used. Values less than the first value use the first color.

The syntax for the buckets clause is

```
buckets float float ...
```

The syntax and assignment of colors is the same as for the scale clause.

If, in the above example, you used the buckets clause instead of the scale clause, the statement would be:

```
colors pctFemale, colors "blue" "gray" "red", buckets 0 50 100;
```

All values greater than or equal to 100 are colored red. Values greater than, or equal to, 50 but less than 100, are gray. All other values are then blue.

Use the buckets clause only with a numeric color variable.

### The legend Clause

The **legend** clause creates a legend of the colors. The legend clause syntax can be any of the following:

```
legend off
legend on
legend "string" "string" ...
legend label "string"
```

The **legend off** clause turns the legend off. The **legend on** clause turns the legend on. It can be omitted if other legend statements are included. Specifying only **legend on** generates the default legend.

The default legend includes a single label to the left (with the name of the field that is mapped to color), and a list of colored labels on the right (with values obtained from the scale clause, the buckets clause, or from the field). To override the strings in the colored labels, specify the strings as:

```
legend "string" "string"
```

To override the label on the left, specify it following the word *label*. To eliminate this label, specify an empty string; that is:

```
legend label ""
```

## Axis Statement

The **axis** statement causes a variable to be used as an axis in the 3D landscape. The variable's values determine where the entities are positioned on the axis. There can be up to three axis statements. Like the size and color statements, the axis statement contains a series of comma-separated clauses, but all of them must be specified in a single statement.

```
axis clause1, clause2,...
```

### The Axis Variable

As with size and color, you can specify a field to be used as an axis. The field can be an array that is indexed by slider dimensions. If the field is an array, it must be of type **number**. If the field is not of type number, it is sorted, and each unique value is assigned a position along the axis.

### The Label Clause

The **label** clause has the form:

```
label "string"
```

The string is used to label the axis. It appears in the landscape, at the end of the axis line. The default label is the name of the axis variable.

### The Max Clause

Normally, the axis variable is mapped directly to the position of the entities along the axis0. The **max** clause lets you normalize the values of the axis variable, so that the maximum value is mapped to the specified max. The max clause's syntax is:

```
max float
```

### The Scale Clause

Instead of using the **max** clause to affect position values, the **scale** clause can be used to scale the values. All values are multiplied by the scale. The scale clause syntax is

```
scale float
```

### The Color Clause

The **color** clause specifies the color used for the axis line and label. It has the form:

```
color "colorname"
```

### The Extend Clause

The **extend** clause specifies whether the axis should be extended automatically to include the value zero. It has the form:

```
extend on
extend off
```

## Summary Statement

The **summary** statement specifies a summation to be calculated over all the entities. The summary is used to color the drawing window in the animation control panel. Like the size and color statements, the summary statement has several clauses that can be specified in one statement, separated by commas, or in separate statements.

```
summary clause1, clause2,...
```

### The Summary Variable

You can specify the variable to be used in the summary. This variable must be of number type. Typically, the summary variable is an array indexed by slider dimensions, so that the summary value varies across the slider dimensions.

### The Color Clause

The **color** clause specifies the color used to display the summary values in the drawing window. It has the form

```
color “colorname”
```

Various shades of the color, from white to the specified color, are used to represent summary values. The minimum summary value is mapped to white, while the maximum summary value is mapped to the specified color. The default summary color is red.

### The Legend Clause

The **legend** clause creates a legend of the summary colors. The legend clause syntax can be any of the following:

```
legend off
legend on
legend label "string"
```

The **legend off** clause turns the legend off. The **legend on** clause turns the legend on. It can be omitted if other legend statements are included. Specifying only **legend on** generates the default legend.

The legend includes a single label to the left (which defaults to the aggregation function and variable used in the summary), and two colored labels on the right (with the minimum and maximum summary values). To override the label on the left, specify it following the word *label*. To eliminate this label, specify an empty string; that is

```
legend label ""
```

## Message Statement

The **message** statement specifies the message displayed when an entity is selected. The syntax is similar to that of the C **printf** statement. A sample message statement is

```
message "%s: $%f, %.0f%% of target, %.0f%% of last year",
         product, sales, pctTarget, pctLastYear;
```

This could produce the following message:

```
furniture: $2425.37, 23% of target, 87% of last year
```

The formats must match the type of data being used:

- Strings must use %.
- Ints must use integer formats (such as %d).
- Floats and doubles must use floating point formats (such as %f).

For details of the **printf** format, see the printf (1) reference (man) page (type **`man printf`** at the shell prompt).

A special format type has been added to **printf**. If the percent sign is followed by a comma (for example, "%,f"), commas are inserted in the number for clarity. Only the United States convention of d,ddd,ddd.dddd is supported, with the decimal point represented by a period, and commas separating every three places to the left of the decimal point. For example, if the above format were:

```
message "%s: $%,f, %,.0f%% of target, %,.0f%% of last year",
         product, sales, pctTarget, pctLastYear;
```

it would produce the message:

```
furniture: $2,425.37, 23% of target, 87% of last year
```

The $, *, h, l, ll, L, and n **printf** format options are not supported.

All values, including the format string, are expressions. Thus, if you had a pctFemale field, but wanted a more gender-neutral message, you could use:

```
message pctFemale>50?"%f%% females":"%f%% males",
         pctFemale>50?pctFemale:100-pctFemale;
```

If pctFemale is 70, the message “70% females” is displayed; if pctFemale is 30, the message “70% males” is displayed. In this case, you can also achieve the same result with a single format string:

```
message "%f%% %s", pctFemale>50?pctFemale:100-pctFemale,
         pctFemale>50?"females":"males";
```

If no message is specified, a default message containing the names and values of all the fields is used.

## Execute Statement

The **execute** statement lets you execute a shell command by double-clicking an object. The syntax is similar to that of the *message* command.

Here is a sample execute statement that uses *xconfirm* to show a window with information about the item. Note that the command line (string) is shown as three lines. In an actual file, this should be on a single line. Multi-line strings are not supported.

```
execute "xconfirm -t '%s' -t 'population %,.0f' -t '%,.0f per
    sq mile' -t '%,.0f sq-miles' > /dev/null", states,
    population, density, sqMiles;
```

This might produce a dialog with the message:

```
CA
64 per sq mile
266,807 sq-miles
```

If there is no execute statement, double-clicking an object has the same effect as single-clicking it.

## The Filter Statement

The **filter** statement specifies that only entities meeting certain filter criteria are displayed initially (see “The View Menu” on page 242 of Chapter 7). The filter criteria are in the form of expressions whose values must all be true or nonzero for an entity to be displayed (expressions are described in “Expressions” on page 608).

The syntax of the **filter** statement is

```
filter expression, expression,...
```

For example, the statement

```
filter state == "CA" || state == "WA", sales > 9000, pctTarget >= 90;
```

specifies that only records from California or Washington state, with sales greater than 9000 and a *pctTarget* value greater than or equal to 90 should be displayed initially.

After the Scatter Visualizer is invoked, the filter criteria can be changed or removed interactively using the filter panel.

## View Options

The **view** section of the configuration file has several options for controlling parameters of the display. These options can appear in a single options statement, separated by commas, or in separate options statements. The syntax of the options statement is

`options` *`option, option,...`*

The following options are available:

- `entity label size` *float*

  controls the size of the entity labels.

- `axis label size` *float*

  controls the size of the axis labels.

- `hide entity label distance` *float*

  controls the distance at which entity labels become invisible. Smaller distances might improve performance, but the labels disappear more quickly.

- `grid color` *`“colorname”`*

  controls the color of the grid.

- `grid size` *float float float*

  controls the spacing between grid lines. It applies the three values to grid lines along the x, y, and z axes, respectively.

- `entity shape` *shapeName*

  specifies the shape used to display entities. *shapeName* can be “cube,” “bar,” or “diamond.”

*Appendix E*

# Creating Data and Configuration Files for the Splat Visualizer

The first part of this appendix describes the types and formats of data supported by the Splat Visualizer. Data input to the Splat Visualizer must be provided as a single file containing raw data, in a tab-separated ASCII text.

The second part discusses the configuration file, which describes how the Splat Visualizer reads in, and displays, the data file.

Both the data and configuration files can be generated automatically by the Tool Manager (see Chapter 3).

**Note:** Read Chapter 8, "Using the Splat Visualizer," before using this appendix.

## The Data File

In its simplest form, the data file consists of a list of lines, each containing a set of fields, each separated by one tab. (Other separators are also allowed, but only one per file can separate each field. See "Input Options" on page 637.) All lines must contain the same fields. The interpretation of the fields is specified by the configuration file, described in the next section. Using the *adultJobs* data file provided as part of the Splat Visualizer package (file */usr/lib/MineSet/splatviz/examples/adultJobs.data*), the first few lines of the input file appear as:

```
BachelorsAdm-clerical3351189.4869565217115
BachelorsExec-managerial2570722.627118644159
BachelorsAdm-clerical2337876.328358209134
BachelorsExec-managerial3034436.85
Bachelors Tech-support1237583.666673
Bachelors Tech-support1313711.333333
Bachelors Tech-support1429878.7419331
```

In this sample file listing, each line consists of six fields, separated by tabs. The first field is a string that identifies level of education. The second field is a string which identifies occupation. The third field identifies the age bin. The fourth field identifies the number of hours per week worked bin. The fifth field quantifies the average gross income. The sixth field is the weight of records in the aggregate (ie the record count, unless record weighting has been used). This data file was derived from */usr/lib/MineSet/data/adult94.data* by performing Tool Manager operations (specifically binning and aggregation).

The data file cannot contain blank lines or comments. Missing or extra data on a line causes an error.

**Note:** One tab (the default separator) separates each field. Do not insert multiple tabs to line up the fields visually; this generates blank fields. The order of the fields must match the format specified by the configuration file.

## Data Types

The Splat Visualizer supports the following seven data types:

- **int** represents a 32-bit signed integer.
- **float** represents a single-precision floating point number. The decimal point is optional. Numbers in exponential “e” notation are also accepted.
- **double** represents a double-precision floating point number. The decimal point is optional when representing a floating point number. Numbers in exponential “e” notation are also accepted. The superior precision of **double** can be useful for accurately representing large numbers, since **float** can represent only seven or eight significant digits accurately. This superior accuracy, however, consumes twice the memory space of **float**.
- **dataString** represents a string that is unlikely to appear multiple times. If it appears multiple times, several copies are made. A **dataString** is typically used to store an address. Addresses are unlikely to be compared, and each record can have a different address.

- **string** represents a string of characters that can appear multiple times in the data file. Unlike a **dataString**, only a single copy of a given string is stored in memory, no matter how many times it appears in the data. This saves much memory for strings appearing many times.

  Comparing **strings** is also much quicker than comparing **dataString**s. Processing is somewhat slower when looking for duplicate strings as they are read in. An example of **string** use is for a division name that appears once for each department in the division. If you are unsure whether to use a **string** or a **dataString**, use a **string**.
- **fixed string** represents a string of fixed length. Like a **dataString**, if a **fixed string** appears multiple times, multiple copies are made. In general, **fixed strings** are used internally for representations of data from data bases, and are generally better to use than **strings** or **dataStrings**.
- **date** represents a date and time. In the data file, **date** must appear in the format MM/DD/YY HH:MM:SS.

### Null Values

Any field element in the data file can also have the value "?" (question mark), indicating an unknown or null value (see the discussion of nulls in Appendix J).

## The Configuration File

The configuration file format is flexible. Words in it must be separated by spaces, and it is case-sensitive. Except for the include statement and text within quoted strings, spacing and line breaks are irrelevant.

### Sections

The configuration file consists of a series of sections, each of which has the form:

*sectionKeyword*

```
{
statements...
}
```

where *sectionKeyword* names the section. The order of the sections is significant, since sections can refer to variables defined in previous sections.

## Defaults Files

As each section is encountered, a special configuration file (referred to as a *defaults file*) is also read in. Defaults files normally contain options statements. These files are read in the following order:

1. The directory */usr/lib/MineSet/splatviz*. This directory usually contains system defaults.
2. The *~/.MineSet* directory (where the tilde [~] indicates your home directory). You can set up personal defaults in this directory.
3. The current directory. This lets you set up defaults for each directory.

Files with the same name can appear in more than one of the above-named directories; in this case, the order given is the one in which the directories are read. If the same option is found in multiple files, the last option read is used. Note that the appropriate section in the configuration file is read after all the defaults files; thus, options in the configuration file override those in the defaults files.

## Statements

A statement has the following form:

```
statementKeyword info ;
```

where *statementKeyword* defines the statement, and *info* varies according to the keyword.

## Variable Names

A variable name can appear in two formats:

- In the first format, it is a letter followed by a number of letters, digits, or underscores. It cannot be a keyword, and should not be quoted.
- In the alternate form, the variable name should be surrounded by back quotes (`‘`). In this form, the variable name can match a keyword, and can contain even non-alphanumeric characters. Configuration files generated automatically by the Tool Manager use this form.

There is no scoping of variable names; a given variable name can only be declared once in the configuration file.

## Options Statements

Many sections have options statements, which have the form

```
options optionName info, optionName info... ;
```

where *optionName* defines the specific option, and *info* depends on the option. In some cases, *optionName* can be more than one word. To maximize the number of allowable variable names, most option names are meaningful only within the appropriate options statement; option names do not conflict with variable names. You can declare several options on the same line, separating them by commas or placing them in several options statements. If two conflicting values for the same option appear, the last value is taken.

## Include Statements

The configuration file can contain lines of the form

```
include "filename"
```

These lines can appear anywhere in the configuration file, but each must be on its own line. The filename must be in quotation marks; anything after the closing quote is ignored. The number of nested includes is unlimited. If a relative pathname (one not beginning with a slash) is specified, the file is first sought in the directory containing the current configuration file. If include statements are present, this might not be the same as the initially loaded configuration file. If it is not found in the directory containing the current configuration file, the include file is sought in the current directory.

## Sinclude Statements

A statement similar to an include is sinclude, which has the form

```
sinclude "filename"
```

This is identical to the include statement, except that no error is given if the file does not exist; instead, the sinclude statement is ignored.

## Strings and Characters

Strings and characters in the configuration file follow C conventions. Strings are in double quotation marks ("), and characters are in single quotation marks (′). All standard backslash conventions are followed (for example, \n represents a new line).

## Comments

Comments begin with a pound (#) symbol at the beginning of a line; anything after this symbol to the end of the line is ignored, up to the end of the line.

## Keywords

The keywords recognized by the Splat Visualizer are listed in Table E-1. Variables cannot have these names unless they are surrounded by back quotes (‘). Tokens appearing only in option statements are not keywords, and can be used for variable names.

**Table E-1** Splat Visualizer Keywords

| | | | |
|---|---|---|---|
| across | average | axis | buckets |
| by | color | colors | weight |
| dataString | date | divide | double |
| execute | expressions | file | float |
| from | include | input | int |
| key | label | legend | max |
| message | min | modulus | monitor |
| off | on | options | opacity |
| scale | separator | sinclude | size |
| slider | string | sum | summary |
| time | to | view | background |

Currently, the keywords **execute**, **monitor**, **weight**, and **time** are not used by the Splat Visualizer.

# The Input Section

The first section of a configuration file is normally the input section. It defines the name and format of the data file. A typical input section might look like this:

```
input {
     file "adultJobs.data";
     enum string `age_bin_k` {"- 20", "20-30", "30-40",
"40-50", "50-60", "60-70", "70+"};
     enum string `hours_per_week_bin_k` {"- 20", "20-25", "25-30",
"30-35", "35-40", "40-45", "45-50", "50-55", "55-60", "60-65",
"65-70", "70+"};
     string `education`;
     string `occupation`;
     enum `age_bin_k` `age_bin`;
     enum `hours_per_week_bin_k` `hours_per_week_bin`;
     double `avg_gross_income`;
     int `count_gross_income`;
}
```

This example states that the input file is called *adultJobs.data*, and that there are six fields: education, occupation, age_bin, hours_per_week_bin, avg_gross_income, and count_gross_income. The education and occupation fields are of type **string**. The *a*ge_bin and hours_per_week_bin are of type **enum**, where the values of these enums is defined by age_bin_k and hours_per_week_bin_k respectively. The column avg_gross_income is of type **double** and the field count_gross_income is of type **int**.

When the **input** section is entered, the defaults file *inputDefaults* is read in.

## File Statements

The **file** statement names the data file to be read. This statement is required. Its form is:

```
file "filename";
```

*filename* must be in double quotation marks. If it is a relative pathname (no leading slash), it is first sought in the directory containing the current configuration file. If include statements are present, this might not be the same as the initially loaded configuration file. If it is not found in the current configuration file's directory, the file is sought in the current directory.

## Enumeration Statements

Enumeration statements declare enumerations, or enums. The enum statement has three forms.

- The first enum statement form is

  ```
  enum type name from value1 to value2 by increment;
  ```

  This declares an enum with values starting at *value1* and incremented by *increment* until they reach or exceed *value2*. For example, the statement

  ```
  enum int age from 20 to 70 by 10;
  ```

  declares age as an enum with the values 20, 30, 40, 50, 60, and 70.

  *Type* must be a number type (**int**, **float**, or **double**) or **date** (see “Dates” on page 634).

- The second enum statement form is

  ```
  enum type name from value1 to value2 across numberOfValues;
  ```

  This declares an enum with values ranging from *value1* to *value2*. The *numberOfValues* is an integer specifying the number of values. For example, the statement:

  ```
  enum int age from 20 to 70 across 6;
  ```

  declares age as an enum with the values 20, 30, 40, 50, 60, and 70.

  *Type* must be a number type (**int**, **float**, or **double**) or **date** (see “Dates” on page 634).

- The third enum statement explicitly lists the enum values. Its form is:

  ```
  enum type name { value1, value2, ..., valueN };
  ```

  *Type* can be any type or date (see “Dates” on page 634).

### Dates

The enum statement includes special support for a date type that handles date and time values starting Jan 1, 1753. The date type is valid only within enum statements. A date enum statement can have the following syntaxes:

```
enum date “format” name from “value1” to “value2” across
        numberOfValues;
enum date “format” name { value1, value2, ..., valueN };
enum date “format” name from “value1” to “value2” by
        “increment”;
```

The *format* string specifies the format of the values; it is useful for controlling how dates are displayed in the animation control panel. The syntax of the *format* string is similar to the **scanf** function in C. Various units of time are represented by special characters preceded by the percent symbol (%). For example,

```
enum date cq “Calendar Q%Q, %Y” from “Calendar Q1, 1980” to “Calendar
Q3, 1985” by “1 quarter”;
```

The “Calendar Q” in the *format* string matches the “Calendar Q” in *value1* and *value2*. The %Q in the *format* string indicates that the next number in *value1* and *value2* is the calendar quarter. The comma and space in the *format* string match the commas and spaces in the values. Finally, the %Y in the *format* string specifies that the year values are next.

Table E-2 lists the characters that can follow the percent symbol and the units of time they represent.

**Table E-2** Characters That Can Follow the Percent Symbol in the Format String

| Character | Time Unit | Precision |
|---|---|---|
| Y | year | 4 |
| Q | calendar quarter | 1 |
| M | month | 2 |
| N | month name | >= 3 |
| D | day | 2 |
| h | hour | 2 |
| m | minute | 2 |
| s | second | 2 |

With the exception of N, each character matches an integer of the specified precision. N matches 3 or more characters giving the English name of the month.

The from-to-by form of the enum statement includes an increment value. For dates, the increment is a quoted string containing an integer, an optional space, and one of the special characters in Table E-2 or one of the symbols **year**, **quarter**, **month**, **day**, **hour**, **minute**, and **second**. The plural forms of these symbols are also accepted. Note that these symbols are not keywords, since they have special meaning only in the increment string. The following are examples of valid increments:

```
“1 year”
“7 days”
“4h”
```

## Data Statements

The data statements declare the fields in the data file. The fields must be declared in the order they appear in the data file. The format of most data statements is

```
type name;
```

where *type* is **int**, **float**, **double string**, **dataString**, **date**, and **fixedString(*n*)**, where *n* is an integer representing the width of the string; *name* is the variable name. Unlike in C, only one variable can be declared per statement.

A data field can also be based on an enumeration. The syntax is

```
enum enumName name;
```

The field must contain **ints** corresponding to the values of the enum. For example, if the enum ageGroup is declared as

```
enum string ageGroup {"below 30", "30-39", "40-49", "50-59",
        "60 or above"};
```

the field age can be declared as

```
enum ageGroup age;
```

The field should contain **ints** between 0 and 4, where 0 is displayed as “below 30,” 1 as “30-39”, and so forth.

Only one variable can be declared per statement.

### Input Options

All **options** statements begin with the word "options" and have one or more comma-separated options.

- The separator option defines the separator between fields in the data file. The default separator is a tab. The syntax is

  ```
  options separator 'char';
  ```

  For example:

  ```
  options separator ':';
  ```

- The backslash option controls whether backslashes in the input data are treated specially or like other characters. The syntax is:

  ```
  options backslash off;
  ```

  ```
  options backslash on;
  ```

  The default is off. If backslash processing is on, separators in the input data preceded by backslashes are treated as regular characters rather than separators. Within strings, this causes standard C-style backslash processing.

## The View Section

The **view** section of a configuration file describes how the data is displayed, including the mapping of sizes, colors, axes, and so on. The default values for these options are in */usr/lib/MineSet/splatviz/view.splatviz.options*. Its form is

```
view
{
viewStatement;
...
}
```

A sample view section is

```
view {
 slider `age_bin`;
 opacity `count_gross_income`;
 color `avg_gross_income`;
 axis `education`, color "grey";
 axis `occupation`, color "grey";
 axis `hours_per_week_bin`, max 100, color "grey";
 options grid size 0 0 0;
 summary `count_gross_income`, color "red";
}
```

When entering the view section, the *viewDefaults* file is read in.

## Slider Statement

The **slider** statement identifies an enum column to be used as a slider dimension. Its syntax is one of the following:

```
slider columnName;
```

The *columnName* name is declared in the input section. If this column contains nulls, the slider includes a beginning position corresponding to those null values.

There can be 0, 1, or 2 slider statements. The first slider statement applies to the horizontal slider, the second to the vertical slider. If there is no slider statement, the resulting display does not include animation.

## Opacity Statement

In the Splat Visualizer, the opacity is based on counts or record weights. If a column is mapped to this requirement, it is used to weight each record (rather than using 1), when computing a value for the opacity. Thus, if you had a column with values for population, density, or the result of a count aggregation, you might want to map this column to the opacity (weight) requirement. If you had no such column, the requirement is left unmapped, and a column of 1's is used by default.

- An opacity type for each axis. (This can be *Max Opacity*, or *Scale Opacity*.)
  - *Max Opacity* lets you specify that an axis is scaled independently to a specified opacity. If one axis has a Max Opacity that is twice as opaque as the other, it will be twice as opaque, regardless of the data values. This option is most useful when comparing axes that are in different units (for example, comparing income to age). This option has no effect on non-numeric data.
  - *Scale Opacity* lets you specify that the axis is scaled based on its maximum value. If two axes have the same Scale Opacity, but one has a maximum that is twice the value of the other, the former will be twice as opaque as the latter. This option is useful for comparing axes with the same units (for example, income vs. expenses). This option does affect the opacity of non-numeric axes.

In the Splat Visualizer, this column (if present) is sum aggregated, and its name is prepended with "sum_". If no column is present, the record count is used. In either case, the values of this column are used to compute opacity. The legend at the bottom of the main window shows this column name after "opacity:".

The **opacity** statement describes how a column is mapped to the opacity of the splats. The opacity statement consists of a series of clauses, separated by commas:

```
opacity clause1, clause2,...
```

Alternatively, the clauses can be given in separate opacity statements.

### The Opacity Variable

The first clause normally contains the name of a field to be mapped to opacity (*count_gross_income*, in the **view** example in “The View Section” on page 637). The field must be of a number type (**int**, **float**, or **double**).

### The Legend Clause

The **legend** clause defines the meaning of the opacity mapping. The legend clause has the following forms:

- `legend off`

  This turns off the opacity legend.

- `legend on`

  This turns on the opacity legend (this is the default). The default legend is:

  `opacity:`*`count`*

  where *`count`* is a column that the tool has created by counting the number of records in each aggregate. If a column was mapped to opacity, the name of this column prepended with "sum_" is shown in the legend. This new column is computed by sum aggregating the column mapped to the opacity requirement.

- `legend label` *"string"*

  This turns the legend on and explicitly sets the legend string. If this form is used, *legend on* is unnecessary.

## Color Statement

The **color** statement describes how values are mapped to colors. The format is similar to the opacity statement, consisting of several clauses that can be separated by commas, or entered as multiple statements. The syntax is:

```
color clause1, clause2,...
```

### Color Naming

Color names follow the conventions of the X window system, except that the names must be in quotes. Examples of valid colors are “green,” “Hot Pink,” and “#77ff42.” The latter is in the form “#*rrggbb*”, in which the red, green, and blue components of the color are specified in hexadecimal value. Pure saturation is represented by ff, a lack of color by 00. For example,”#000000” is black, “#ffffff” is white, “#ff0000” is red, and “#00ffff” is cyan.

### The Color Variable

As with opacity, you also can specify a column to be mapped to splat color. If the column is a number type, the scale and buckets clauses described below can be used to map a range of colors to the values of the field.

### The colors Clause

The **colors** clause specifies the colors to be used. The colors clause's syntax is:

```
colors "colorname" "colorname"...
```

The format for *colorname* is described in "Color Naming" on page 640. Note that there are no commas between the colors, because commas are used to separate clauses in the color statement. A sample colors clause is:

```
colors "red" "gray" "blue"
```

Colors in the list are subsequently referred to by their index, starting at zero. In the above example, red is color 0, gray is color 1, and blue is color 2.

If there is no colors statement, colors are chosen randomly. If there is a colors statement, at least as many colors must be specified as are to be mapped.

### The scale Clause

The **scale** clause allows assignment of values to a continuous range of colors. For example, when displaying a percentage, red can be assigned to 0%, gray to 50%, and blue to 100%. Intermediate values are interpolated; for example 25% is pinkish, and 55% is a slightly bluish gray.

The syntax for the scale clause is

```
scale float float ...
```

The first value is mapped to color 0, the second to color 1, and so forth. The colors statement must contain at least as many colors as are to be mapped to the largest index.

Values in this statement must be in increasing order. Any value less than the first color is assigned the value of the first color. Any value greater than the last value is assigned the last color. Intermediate values are interpolated.

For example, assume the pctFemale field indicates what percentage of the group is female, and you want to map a group that is 100% female to red, 100% male to blue, and 50% each to gray. The colors statement for this is:

```
colors pctFemale, colors "blue" "gray" "red", scale 0 50 100;
```

Use the scale clause only in conjunction with a numeric color variable.

### The buckets Clause

The **buckets** clause is similar to the scale clause without interpolation. All values are rounded down to the highest value in the clause, and that exact color is used. Values less than the first value use the first color.

The syntax for the buckets clause is

```
buckets float float ...
```

The syntax and assignment of colors is the same as for the scale clause.

If, in the above example, you used the buckets clause instead of the scale clause, the statement would be:

```
colors pctFemale, colors "blue" "gray" "red", buckets 0 50 100;
```

All values greater than or equal to 100 are colored red. Values greater than, or equal to, 50 but less than 100, are gray. All other values are then blue.

Use the buckets clause only with a numeric color variable.

### The legend Clause

The **legend** clause creates a legend of the colors. The legend clause syntax can be any of the following:

```
legend off
legend on
legend "string" "string" ...
legend label "string"
```

The **legend off** clause turns the legend off. The **legend on** clause turns the legend on. It can be omitted if other legend statements are included. Specifying only **legend on** generates the default legend.

The default legend includes a single label to the left (with the name of the field that is mapped to color), and a list of colored labels on the right (with values obtained from the scale clause, the buckets clause, or from the field). To override the strings in the colored labels, specify the strings as:

```
legend "string" "string"
```

To override the label on the left, specify it following the word *label*. To eliminate this label, specify an empty string; that is:

```
legend label ""
```

## Axis Statement

The **axis** statement causes a variable to be used as an axis in the 3D landscape. The variable's values determine where the entities are positioned on the axis. There can be up to three axis statements. Like the size and color statements, the axis statement contains a series of comma-separated clauses, but all of them must be specified in a single statement.

```
axis clause1, clause2,...
```

### The Axis Variable

As with size and color, you can specify a field to be used as an axis. The field can be an array that is indexed by slider dimensions. If the field is an array, it must be of type **number**. If the field is not of type number, it is sorted, and each unique value is assigned a position along the axis.

### The Label Clause

The **label** clause has the form:

```
label "string"
```

The string is used to label the axis. It appears in the landscape, at the end of the axis line. The default label is the name of the axis variable.

### The Color Clause

The **color** clause specifies the color used for the axis line and label. It has the form:

```
color "colorname"
```

## Summary Statement

The **summary** statement specifies aggregate information to be calculated for all data defined by the slider position. The summary is used to color the drawing window in the animation control panel. Like the opacity and color statements, the summary statement has several clauses that can be specified in one statement, separated by commas, or in separate statements.

```
summary clause1, clause2,...
```

### The Summary Variable

You can specify the variable to be used in the summary. This variable must be of number type. If no summary variable is specified, *sum of counts* is used. If a variable is specified, then the weighted average of that variable (for all the data at the slider location) is used.

### The Color Clause

The **color** clause specifies the color used to display the summary values in the drawing window. It has the form

```
color “colorname”
```

Various shades of the color, from white to the specified color, are used to represent summary values. The minimum summary value is mapped to white, while the maximum summary value is mapped to the specified color. The default summary color is red. If no slider variable is specified, this statement has no effect.

### The Legend Clause

The **legend** clause creates a legend of the summary colors. The legend clause syntax can be any of the following:

```
legend off
legend on
legend label "string"
```

The **legend off** clause turns the legend off. The **legend on** clause turns the legend on. It can be omitted if other legend statements are included. Specifying only **legend on** generates the default legend.

The legend includes a single label to the left (which defaults to the aggregation function and variable used in the summary), and two colored labels on the right (with the minimum and maximum summary values). To override the label on the left, specify it following the word *label*. To eliminate this label, specify an empty string; that is

```
legend label ""
```

## View Options

The **view** section of the configuration file has several options for controlling parameters of the display. These options can appear in a single options statement, separated by commas, or in separate options statements. The syntax of the options statement is

`options` *`option, option,...`*

The following options are available:

- `axis label size` *float*

  controls the size of the axis labels.

- `background color “colorname”`

  controls the initial color of the background..

- `hide label distance` *float*

  controls the distance at which axis labels become invisible. Smaller distances might improve performance, but the labels disappear more quickly.

- `grid color` *`“colorname”`*

  controls the color of the grid.

- `grid size` *float float float*

  controls the spacing between grid lines. It applies the three values to grid lines along the x, y, and z axes, respectively.

- `shape` *splatType*

  specifies the type of splat used. The *shapeName* can be “constant,” “linear,” "gaussian","texture", or “sphere.”

*Appendix F*

# Creating Data and Configuration Files for the Rules Visualizer

This appendix describes

- data and configuration files
- command-line operation
- example files and commands

for each of the three components of the Rules tool (association data converter, association rules generator, and rule visualizer).

The Rules tool is completely operable via the Tool Manager (see Chapter 3). Alternatively, all components of the Rules tool can be invoked via the command-line interface and/or files created with a text editor, such as jot, vi, or Emacs. This second mode of operation lets you create configuration files needed for the association data converter and the association rules generator. It also lets you set up a process (using standard UNIX facilities) to run the association data converter and the association rules program nightly on new data using those configuration files.

The examples used in the following sections can be found in the */usr/lib/MineSet/assoccvt/examples/* and */usr/lib/MineSet/assocgen/examples/* directories. Descriptions and instructions for use can be found in the README file in these directories.

**Note:** Read Chapter 9, “Using the Rules Visualizer,” before using this appendix.

# The Association Data Converter

The association data converter converts a raw data file (such as a user's ASCII data file) into a file of the format used by the association rule generator program. The association data converter requires as input a raw data file and a format file. Its output is a specially formatted data file for use by the association rules generator. Note that the process described below is for preparing data files for use by the associations program manually (that is, via the command line). When the associations program is run via the Tool Manager, this process is done automatically.

In the following description, %s denotes a string-valued input, %f denotes a floating-point number input, and %d denotes an integer number input.

## Association Data Converter File Requirements

The association data converter requires:

- a *raw data file* (this is the user's data for running associations) in one of two accepted formats.
- a *format file*, which describes the raw data file's format.

### The Raw Data File

The raw data file input from the association data converter can be in one of two formats:

- Single-item format
  - Each record has one item and an identifier.
  - All items with the same identifier are grouped on successive lines in the file (they need not be sorted, just grouped.)
  - Each record has the same length.
- Multiple-item format
  - Each record has multiple items and an identifier.
  - All items associated with the same identifier are in a single record.
  - Each record has the same length.

### The Format File

The format file specifies the format of the raw data file to the association data converter.

The format file follows one of the forms listed in Table F-1 or Table F-2, depending on the raw data file’s format (single or multiple item).

**Table F-1** Single-Item Format

| **List of required items in the format file (Format 1)** |
|---|
| Letter “S” to indicate single-item format file |
| Number of bytes in each record (excluding record separator, such as LF) |
| Number of fields that make up the identifier |
| Total number of bytes in the identifier |
| Offset and length in bytes for each field that makes up the identifier |
| Number of fields that make up the item |
| Total number of bytes in the item |
| Offset and length in bytes for each field that makes up the item |
| Description flag indicating if descriptions should be produced along with names (either a 0 [meaning No] or 1 [meaning Yes]) |
| If the description flag is 1, the following are required: |
| Number of fields that make up the description |
| Total number of bytes in the description |
| Offset and length in bytes for each field that makes up the description |

**Table F-2** Multiple-Item Format

| **List of required items in the format file (Format 2)** |
|---|
| The letter “M” to indicate multiple-item format file |
| Number of bytes in each record (excluding record separator such as LF) |
| Number of items in each record |
| For each item: |
| Name of the item (column name/domain) |
| Number of fields of the record that make up the item |
| Total number of bytes in the item |
| Number of buckets (discrete bins or categories); 0 for categorical items |
| Offset and length in bytes for each field that makes up item |

## Files Generated by the Association Data Converter

The association data converter generates two files:

- The *output data file* contains the converted data from the raw data file in a format required by the association rules generator.
- The *output names file* contains auxiliary descriptor information used by the association rules generator.

## The Association Data Converter Command-Line Operation

Table F-3 lists the set of options for controlling the association data converter. A description of each option follows the table. An example of invoking the program is:

```
assoccvt -ifile sing.data -ofile sing.bin sing.format sing.names
```

Options for controlling data conversion from raw to internal format are listed below. A description of each option follows the table.

**Table F-3** Options for the Association Data Converter

| Option Format | Required | Default Value | Comments |
|---|---|---|---|
| -ifile %s | no | stdin | Name of raw data file (input) |
| -ofile %s | no | stdout | Name of output data file |
| -isize %d | no | 4 | Size of binary numbers in output file |

**-ifile %s**
Specifies the name of the raw data file, which serves as input to the association data converter. This file contains the data to be converted.

**-ofile %s**
Specifies the name of the file that contains the data converted by the association data converter.

**-isize %d**
Specifies the binary integer size in the output data file.

There are two required arguments on the association data converter command line:

- The name of the format file to be used by the association data converter
- The name of the file containing the description of the integer codes in the output data file

## Association Data Converter Examples

The following commands illustrate the use of the association data converter on the example files in */usr/lib/MineSet/assoccvt/examples*. The file *sing.data* is an example of data in the single item format and has some simple grocery store transactions. Each line has a transaction number and the name of an item bought in that transaction. The format of this file is described by *sing.format*. The file *mult.data* is an example about automobiles and has data about cars of different origin (American, Japanese, European) regarding attributes such as mpg, weight, etc. The values for these attributes are in discrete ranges rather than exact numbers. The format of this file is described by the file *mult.format*.

```
assoccvt -ifile sing.data -ofile sing.bin sing.format sing.names
assoccvt -ifile mult.data -ofile mult.bin mult.format mult.names
```

To test whether the files for data conversion are correctly installed, run any or all of the following commands from the shell command line. Then, using the UNIX *diff* command, compare the files created to those with the same name in */usr/lib/MineSet/assoccvt/examples*.

Then compare *sing.bin* with */usr/lib/MineSet/assoccvt/examples/sing.bin*, and compare *sing.names* with */usr/lib/MineSet/assoccvt/examples/sing.names*.

Enter:

```
assoccvt -ifile mult.data -ofile mult.bin mult.format mult.names
```

Then compare *mult.bin* with */usr/lib/MineSet/assoccvt/examples/mult.bin*; and compare *mult.names* with */usr/lib/MineSet/assoccvt/examples/mult.names*.

## Association Rules Generator

The association rules generator generates association rules among items in a set of data. Its required inputs are described in the following subsections. Its output is a specially formatted rules file, which can be used by the rule visualization part of the Rules Visualizer (see Chapter 9).

### Association Rules Generator Files Requirements

The association rules generator programs, *assocgen* and *mapassocgen*, require:

- a *data file* in the internally required format
- a *configuration file*, which specifies various program parameters
- (for *mapassocgen* only) a *mapping file*, which specifies the mapping between hierarchical levels
- (for *mapassocgen* only) a *description file*, which specifies a string description for each item at a specific hierarchical level

### Association Rules Generator Command-Line Operation

Rules are generated by applying one of two commands, along with one or more parameters. The command used depends on whether the data for which rules are to be generated are non-hierarchical or hierarchical (see “Starting the Association Rules Generator Part” in Chapter 9). The commands are:

- *assocgen*—which generates rules based on nonhierarchical data.
- *mapassocgen*—which generates rules based on hierarchical data.

Numerous options control the rule-generation process. Many of these are common to both the *assocgen* and *mapassocgen* commands. Options fall into one of the following categories:

- *Rule Generation Options*— control the process of rule generation.
- *Rule Restriction Options*—place restrictions on the set of generated rules.
- *Hierarchical Data Options*—define parameters used only when generating rules from hierarchical data (using *mapassocgen*.)

The **-ropts** string separates the first two sets of options. This string is required if there are any options from the second or third set.

The **-vopts** string separates the second and third sets of options. This string is required if there are any options from the third set.

An example rule generation command line (for which the parameters are explained in the following sections) might be:

```
assocgen -prev 20 -tran mult.bin -ropts -names mult.names
        -rout -mult.rules
```

### Rule Generation Options Common to *assocgen* and *mapassocgen*

Table F-4 lists the set of options for controlling the rule-generation process. A description of each option follows the table.

**Table F-4** Options for Controlling Rule Generation

| Option Format | Default Value | Comments |
|---|---|---|
| -tran %s | (stdin) | Data file path |
| -prev %f | (1.0) | Prevalence threshold (as a percentage) |
| -uniq %d | | Number of items in dataset |
| -dir %s | (/usr/tmp) | Directory for temporary files |
| -tprefix %s | (A_) | Prefix for temporary files |
| -msg %s | (assocgen.msg) | Message file |

**-tran %s**
Specifies the path for the file. By default, the file is read from *stdin*.

**-prev %f**
Specifies the minimum prevalence threshold as a percentage of the total number of records. The default is 1.0%. If the prevalence threshold results in a minimum count less than 3, an error message is displayed, and no rules are generated.

**-uniq %d**
Specifies the number of unique or distinct items across all records (if known). Specifying this (or an upper bound) speeds processing.

**-dir %s**
Specifies the directory to store temporary files, including the message file (see **-msg,** below). The default is ./ .

**-tprefix %s**
Specifies the prefix to be used for temporary files, except the message file (see **-msg,** below). The default prefix is *A_*.

**-msg %s**
Specifies the message file. The default is *assocgen.msg*.

### Rule Restriction Options Common to *assocgen* and *mapassocgen*

Table F-5 lists the set of options for restricting generated rules. Options in this set are used after those listed in Table F-4 and separated on the command line from the former options by **-ropts**. A description of each option follows the table.

**Table F-5** Options for Restricting Generated Rules

| Option Format | Default Value | Comments |
|---|---|---|
| -pred %f | (50.0) | Minimum predictability (as a percentage) |
| -rnum | (FALSE) | Print only the number of rules generated |
| -rsort %d [%s]+ | (4 RHS PRED PREV LHS) | Field sorting order. Fields can be all or any subset. PRED and PREV are sorted in descending order. |
| -names %s | | Name of file containing item descriptions |
| -rout %s | (stdout) | Name of file in which to output rules |

**-pred %f**
Specifies the minimum predictability threshold for rules. Rules with a predictability below this value are not generated. The default is 50%.

**-rnum**
Output only the number of rules generated, not the rules themselves.

**-rsort %d [%s]+**
Specifies the sort order for rules. The first number denotes the number of sorting fields specified; the second field of the option specifies the fields to be sorted. The four keys for sorting rules are (in order):

- RHS—items on right-hand side of rule
- PRED—predictability of rule
- PREV—prevalence of rule
- LHS—items on left-hand side of rule

**-names %s**
Specifies the name of the file which contains the descriptions of the items. This is typically the names file created during the *assoccvt* step.

**-rout %s**
Specifies the name of the file to which rules are to be written. If this is not specified, rules are written to *stdout*.

### Hierarchical Data Options Common to *assocgen* and *mapassocgen*

There are no hierarchical data options common to both assocgen and mapassocgen. See "Hierarchical Data Options for mapassocgen Only" on page 657.

### Rule-Generation Options for *mapassocgen* Only

In addition to the options provided by the *assocgen* program, the *mapassocgen* program provides two additional options (Table F-6). These options are rule-generation options and thus must be specified in the first set of options (the set before the **-ropts** string). A description of each option follows the table.

**Table F-6** Options for the *mapassocgen* Command

| Option Format | Comments |
|---|---|
| -agg %d | Hierarchical level for which rules are to be obtained. |
| -map %d [%d]+ %s | File for mapping lowest hierarchical level to level for which rules are to be obtained. |

**-agg %d**
Specifies the level of the hierarchy at which the rules are desired. Level 0 is the lowest level of the hierarchy, level 1 is the next level up in the hierarchy, and so on.

**-map %d [%d]+ %s**
Specifies a file that allows the *mapassocgen* program to map the lowest level in the hierarchy (present in the data) to the level at which the rules are desired. The first number specifies the total number of levels of aggregation. Next, for each level, a number denotes the size in bytes for the mapping value for that level. Finally, the path is given for the map file.

The values at the lowest level are the integers 0, 1, 2, 3, and so on. The map file lists the values at the new level (or levels) in the same order. First list the value(s) corresponding to level 1, then the value(s) corresponding to value 2, and so on. The values at the lowest level (level 0) are omitted because the list of values is in the implicit order 0, 1, 2, 3, and so forth.

Table F-7 provides an example from the dataset used in the "Hierarchical Data Example" section. This example has two hierarchical levels:

**Table F-7** Example Hierarchy

| Level 0 | Level 1 |
|---|---|
| Milk | Dairy |
| Chips | Snack |
| Coffee | Beverage |
| Eggs | Dairy |
| Tea | Beverage |
| Soda | Snack |
| Cheese | Dairy |
| Butter | Dairy |

The first line in the mapping file (*/usr/lib/MineSet/assocgen/examples/synth.map*) indicates that the value "0" at the lowest level is mapped to value "1" at the next level; the second line indicates that the value "1" at the lowest level is mapped to value "0" at the next level; and so forth.

### Rule Restriction Options for *mapassocgen* Only

There are no rule restriction options specific to *mapassocgen* only. See "Rule Restriction Options Common to assocgen and mapassocgen" on page 654.

### Hierarchical Data Options for *mapassocgen* Only

The option used for hierarchical data is listed in Table F-8. A description follows the table.

**Table F-8** Options Set 3

| Option | Comments |
|---|---|
| -lvldesc %d %s | Hierarchical level, string description file |

**-lvldesc %d %s**
Specifies the hierarchical level and the corresponding string description file. Each string description file must be on a separate line. The strings are mapped, in order, to items 0, 1, 2, 3, and so forth, at the hierarchy level.

This option follows all other options and must be separated from them by **-vopts**.

## Association Rule Examples

Assume you have the data listed in Table F-9. This example is based on the data in the file */usr/lib/MineSet/assoccvt/examples/synth.data*. In this example, each row represents one transaction, and the transaction id is implicit.

**Table F-9** Data Example 2

| Item | Item | Item |
|---|---|---|
| Milk | Chips | Coffee |
| Milk | Chips | Eggs |
| Milk | Chips | Coffee |
| Chips | Coffee | Eggs |
| Milk | Coffee | Cheese |
| Milk | Eggs | Cheese |
| Milk | Tea | Butter |
| Eggs | Tea | Soda |
| Eggs | Tea | Soda |
| Eggs | Tea | Soda |

After using *assocgen* on the file produced by running the sample data in Table F-9 through *assoccvt*, the rule file that is output has the following format:

```
1    1    30.0000  75.00   60.00 Item=Chips      Item=Milk
```

The first pair of numbers denotes the number of items on the LHS and RHS of the rule, respectively. These are always 1's, since only a single item is supported for the LHS and the RHS. The next three numbers denote (in percentages) the prevalence, predictability, and expected predictability. Then the LHS item is listed, followed by the RHS item. In the example above, the LHS is item "Item=Chips", the RHS is item "Item=Milk."

The expected predictability is the frequency of occurrence of the RHS items. The difference between expected predictability and observed predictability is a measure of the increase in predictive power due to the presence of the LHS rule. Expected predictability gives an indication of what the predictability would be if there were no relationship between the items.

### Nonhierarchical Data Example

Assume the minimum prevalence threshold is 30% (3 records out of 10 in the example below). With a default minimum predictability threshold of 50%, and given the input file described above, the *assocgen* program generates the set of rules shown in Table F-10.

**Table F-10** Rule Generation Example 1

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 1 | 30.0000 | 75.00 | 60.00 | Item=Chips | Item=Milk |
| 1 | 1 | 30.0000 | 75.00 | 60.00 | Item=Coffee | Item=Milk |
| 1 | 1 | 30.0000 | 75.00 | 40.00 | Item=Coffee | Item=Chips |
| 1 | 1 | 30.0000 | 50.00 | 40.00 | Item=Milk | Item=Chips |
| 1 | 1 | 30.0000 | 75.00 | 40.00 | Item=Chips | Item=Coffee |
| 1 | 1 | 30.0000 | 50.00 | 40.00 | Item=Milk | Item=Coffee |
| 1 | 1 | 30.0000 | 100.00 | 60.00 | Item=Soda | Item=Eggs |
| 1 | 1 | 30.0000 | 75.00 | 60.00 | Item=Tea | Item=Eggs |
| 1 | 1 | 30.0000 | 100.00 | 40.00 | Item=Soda | Item=Tea |
| 1 | 1 | 30.0000 | 50.00 | 40.00 | Item=Eggs | Item=Tea |
| 1 | 1 | 30.0000 | 75.00 | 30.00 | Item=Tea | Item=Soda |
| 1 | 1 | 30.0000 | 50.00 | 30.00 | Item=Eggs | Item=Soda |

The fields in each line correspond to

- the number of items on the LHS of the rule (always 1)
- the number of items on the RHS of the rule (always 1)
- the prevalence
- the predictability
- the expected predictability (explained in the following section)
- the name (or code) of the item on the LHS
- the name (or code) of item on the RHS

### Hierarchical Data Example

Using the example dataset in “Nonhierarchical Data Example” on page 659, Table F-11 shows the mapping of the values at the lowest level to the highest level. The first column represents data at the lowest hierarchical level, while the values Snack, Dairy, and Beverage in the second column represent a higher hierarchical level.

**Table F-11** Example Hierarchy

| Level 0 | Level 1 |
|---|---|
| Milk | Dairy |
| Chips | Snack |
| Coffee | Beverage |
| Eggs | Dairy |
| Tea | Beverage |
| Soda | Snack |
| Cheese | Dairy |
| Butter | Dairy |

In this example, value “Milk” is mapped to “Dairy”, value “Chips” is mapped to “Snack”, and so on. “Snack”, “Dairy”, and “Beverage” can be represented as integers 0, 1, and 2 in the mapping file. Then, the **-map** option can be specified as

```
-map 2 4 synth.map
```

where 2 indicates two levels in the hierarchy, 4 indicates a 4-byte integer for each value in the map file, and *synth.map* is the name of the map file. The binary file *synth.map* for our running example can be found in */usr/lib/MineSet/assocgen/examples* and contains the following values (for purposes of illustration, numbers are provided in decimal rather than binary form):

```
1 0 2 1 2 0 1 1
```

To obtain rules at the lowest hierarchical level, specify **-agg 0**. The program output for this is shown in Table F-12.

**Table F-12** Example of Rules at the Lowest Hierarchical Level

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 1 | 30.0000 | 75.00 | 60.00 | 0 \| 1 | 1 \| 0 |
| 1 | 1 | 30.0000 | 75.00 | 60.00 | 2 \| 2 | 1 \| 0 |
| 1 | 1 | 30.0000 | 75.00 | 40.00 | 2 \| 2 | 0 \| 1 |
| 1 | 1 | 30.0000 | 50.00 | 40.00 | 1 \| 0 | 0 \| 1 |
| 1 | 1 | 30.0000 | 75.00 | 40.00 | 0 \| 1 | 2 \| 2 |
| 1 | 1 | 30.0000 | 50.00 | 40.00 | 1 \| 0 | 2 \| 2 |
| 1 | 1 | 30.0000 | 100.00 | 60.00 | 1 \| 7 | 1 \| 3 |
| 1 | 1 | 30.0000 | 75.00 | 60.00 | 0 \| 5 | 1 \| 3 |
| 1 | 1 | 30.0000 | 100.00 | 40.00 | 1 \| 7 | 0 \| 5 |
| 1 | 1 | 30.0000 | 50.00 | 40.00 | 1 \| 3 | 0 \| 5 |
| 1 | 1 | 30.0000 | 75.00 | 30.00 | 0 \| 5 | 1 \| 7 |
| 1 | 1 | 30.0000 | 50.00 | 30.00 | 1 \| 3 | 1 \| 7 |

When listing each item, the program shows the complete hierarchical description. For example, 0|1 indicates that item 1 (“Chips”) is mapped to value 0 (“Snack”) at the next higher level in the hierarchy. If you specify **-agg 1**, you get the rules at the next higher level of the hierarchy (which, for this example, is the top level):

```
1       1       80.0000   80.00    80.00  1     0
1       1       80.0000  100.00   100.00  0     1
```

To see the strings “Snack,” “Beverage,” and “Dairy” instead of values 0, 1, and 2 at the top-level hierarchy, specify a third set of options (described in the “Example of Applying Description Files” on page 662).

### Example of Applying Description Files

Using the example in “Hierarchical Data Example” on page 660, you can specify a description file for the top-level hierarchy (level 1) as follows:

```
mapassocgen -tran <dataFileName> -agg 1 -map 2 4
        <hierarchyMappingFileName> -ropts -vopts
        -lvldesc 1 <level1descriptionFileName>
        -rout <rulesFileName>
```

The description file *level1descriptionFileName* now looks like this:

```
Snack
Dairy
Beverage
```

The rules at level 1 of the hierarchy then appear like this:

```
1       1       80.0000   80.00    80.00  Dairy    Snack
1       1       80.0000  100.00   100.00  Snack    Dairy
```

Similarly, you can specify a description file for the items at the lowest level. If the description file, *synth0.names*, looks like this:

```
Milk
Chips
Coffee
Eggs
Tea
Soda
Cheese
Butter
```

then item 0 is mapped to “Milk,” item 1 is mapped to “Chips,” and so on. Then if you specify the options string

```
-lvldesc 1 synth1.names -lvldesc 0 synth0.names
```

after **-vopts**, the rules generated at the lowest hierarchical level are shown in Table F-13.

**Table F-13** Second Example of Rules Generated at Lowest Hierarchical Level

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 1 | 30.0000 | 75.00 | 60.00 | Snack \| Chips | Dairy \| Milk |
| 1 | 1 | 30.0000 | 75.00 | 60.00 | Beverage \| Coffee | Dairy \| Milk |
| 1 | 1 | 30.0000 | 75.00 | 40.00 | Beverage \| Coffee | Snack \| Chips |
| 1 | 1 | 30.0000 | 50.00 | 40.00 | Dairy \| Milk | Snack \| Chips |
| 1 | 1 | 30.0000 | 75.00 | 40.00 | Snack \| Chips | Beverage \| Coffee |
| 1 | 1 | 30.0000 | 50.00 | 40.00 | Dairy \| Milk | Beverage \| Coffee |
| 1 | 1 | 30.0000 | 100.00 | 60.00 | Dairy \| Butter | Dairy \| Eggs |
| 1 | 1 | 30.0000 | 75.00 | 60.00 | Snack \| Soda | Dairy \| Eggs |
| 1 | 1 | 30.0000 | 100.00 | 40.00 | Dairy \| Butter | Snack \| Soda |
| 1 | 1 | 30.0000 | 50.00 | 40.00 | Dairy \| Eggs | Snack \| Soda |
| 1 | 1 | 30.0000 | 75.00 | 30.00 | Snack \| Soda | Dairy \| Butter |
| 1 | 1 | 30.0000 | 50.00 | 30.00 | Dairy \| Eggs | Dairy \| Butter |

# Rules Visualization

The rules visualization part of the Rules Visualizer graphically displays rules resulting from the association rules generator.

## Rules Visualization File Requirements

The rules visualization requires:

- a *rules* file in the internally required format.
- a *configuration* file, which specifies various display parameters.

### The Rules File

The rules file is generated by the association rules generator (See "Association Rules Generator" on page 652).

### The Configuration File

The configuration file describes how the data from the rules file is to be displayed. This file consists of three sections:

- The **input** section—specifies the rules file to be used.
- The **expressions** section (optional)—creates new viewing parameters.
- The **view** section—specifies how the data is presented.

An example configuration file, *group.ruleviz,* is

```
input {
   file “group.rules”;
}

expressions {
   float ratio = expected / predictability;
}

view {
   height predictability, max 10, legend on;
   disk height expected, legend on;
   color prevalence, scale 0 10, colors “white” “purple”,
   legend on;
   options grid size 6;
   message “LHS: %s\nRHS: %s\npredictability: %.2f
   expected: %.2f  prevalence: %.2f”,
   LHS, RHS, predictability, expected, prevalence;
}
```

### Input Section

The input section has the form:

```
input { file “rulesFilename”; }
```

The file statement specifies the rules file. It is the only statement in the input section.

### Expressions

The expressions section of the configuration file defines field names to be used subsequently in both this section itself and in the view section. This section specifies new fields in terms of the fields in the rules file. For example, the following line specifies the ratio between predictability and expected predictability:

```
expressions { float ratio = predictability / expected; }
```

The expression section uses field names defined in the rules file. These field names and their types are listed in Table F-14.

**Table F-14** Field Names and Types for Rules File

| Rules File Field Name | Type | Notes |
|---|---|---|
| numLHS | int | Always 1. |
| numRHS | int | Always 1. |
| prevalence | float | |
| predictability | float | |
| expected | float | |
| LHS | string | |
| RHS | string | |

Expressions are defined with a combination of field names and operators. The operations and their symbols are listed in Table F-15.

**Table F-15** Operators Used With Expressions

| Operator | Description |
|---|---|
| + | Addition |
| - | Subtraction |
| * | Multiplication |
| / | Division |
| % | Modulus |
| == | Equals |
| != | Not equals |
| > | Greater than |
| < | Less than |
| >= | Greater than or equal to |
| <= | Less than or equal to |
| && | AND |
| \|\| | OR |
| ! | NOT |
| & | Bitwise AND |
| \| | Bitwise OR |
| ^ | Bitwise XOR |
| A?B:C | If (A), then B else C |

Also, the following functions are available:

- **divide**(x, y, z) divides *x* by *y*, unless *y* is zero. If *y* is zero, the result is *z*; this is equivalent to y==0 ? z : x/y.
- **modulus**(x, y, z) is similar to **divide**, but for modulus.

The following sample code illustrates some of the possible expressions:

```
float variable0 = expected / predictability;
float variable1 = prevalence +1;
float variable2 = variable1 - 1;
float variable3 = variable1 * 3;
float variable5 = 10 % 4;
float variable6 = variable1;
float variable7 = variable1 || 87;
float variable8 = variable1 && 34;
float variable9 = (7 < 5 ? 4 : 3);
float variable10 = divide(15,8,9);
float variable11 = modulus(15,0,9);
float variable12 = (“abc” < “def” ? 1 : 2);
int variable 13 = (int) variable 12;
```

Expressions using **int** and **float** promote both sides to float. Expressions using **int** and **double**, or **float** and **double**, promote both sides to double. The result of a relational expression (for example, ==, <) is always an **int**. Type casting is also supported.

Strings can be compared using relational expressions; the strings are compared lexicographically.

### View Section

The view section describes how data is presented. A rule is displayed at the junction of its left-hand-side and right-hand-side items. The view section lets you specify what is shown at the junctions.

The view section has the form:

```
view { viewStatement; ... }
```

You can view bars, disks, and labels at the junctions. The bars and disks have heights and colors.

### Height Statement

The height statement describes how the rules are mapped to the heights of bars and disks. The height statement consists of a series of clauses, separated by commas. Alternatively, it can be specified as multiple height statements.

```
height sales, max 2.0;
```

or

```
height sales;
max 2.0;
```

The first clause normally contains the name of a column that is to be mapped to bar height (sales, in the example). The column must be of a number type (int, float, or double); float is the most efficient. If no height column is specified, all bars are flat, and the remaining height clauses have no effect.

The **max clause** specifies the height of the tallest bars. If no max clause is specified, the height is 1.0 in arbitrary units. If, after looking at the view, you see that the heights are too low or too high, use the max clause to adjust them. The syntax of the max clause is

```
max float
```

where *float* is a floating point number (the decimal point is optional). For example, to specify the maximum height as 2, enter:

```
max 2
```

The **scale clause** scales the arbitrary height values; all values are multiplied by the scale. The syntax of the scale clause is

```
scale float
```

Do not use the scale clause with the max clause.

The **legend clause** specifies whether mapping information is displayed in the lower window pane. This information is about mapping between display entities and data values (for example, bar height corresponds to predictability values). The legend clause has the following syntaxes:

- legend off

  This turns off the height legend (this is the default).

- legend on

  This turns on the height legend. The legend can be changed by using the legend label form, in which case legend on is unnecessary. By default, the legend has the following syntax:

  ```
  height:varname
  ```

  where *varname* is the name of the variable that is mapped to height.

- The legend can be changed by using the legend label form:

  ```
  legend label "string"
  ```

  If legend label is used, legend on is unnecessary.

By default, the height statement affects bars. To specify disks, begin the statement with **disk height**:

```
disk height sales, max 2.0;
```

If no max or scale clause is specified for disk heights, the disks inherit the clause specified for bars.

#### Color Statement

The color statement describes how values are mapped to colors. The format is similar to the height statement, consisting of several clauses that can be separated by commas, or entered as multiple statements.

**Color names** must be in quotation marks. Examples of valid colors are “green,” “Hot Pink,” and “#77ff42.” The last one is in the form “#*rrggbb*”, in which the red, green, and blue components of the color are specified as hexadecimal values. Pure saturation is represented by ff, a lack of color by 00. For example, “#000000” is black, “#ffffff” is white, “#ff0000” is red, and “#00ffff” is cyan. You can use the colorview program to determine the names of the colors available on your workstation.

The **color variable** lets you map a column to a color. The column must be a number type. There is no normalization of colors.

The **colors clause** specifies the colors to be used. The colors clause syntax is:

```
colors "colorname" "colorname"...
```

The format for *colorname* has been described above. Note that there are no commas between the colors. This is because commas are used to separate clauses in the color statement. A sample colors clause is

```
colors "red" "gray" "blue"
```

Colors in the list are subsequently referred to by their index, starting at zero. In the above example, red is color 0, gray is color 1, and blue is color 2.

If there is no colors statement, all bars have the same color.

The **scale clause** allows assignment of values to a continuous range of colors. For example, when displaying a percentage, red can be assigned to 0%, gray to 50%, and blue to 100%. Intermediate values are interpolated; for example, 25% is pinkish, and 55% is a slightly bluish gray.

The syntax for the scale clause is

```
scale float float ...
```

The first value is mapped to color 0, the second to color 1, and so forth. The colors statement must contain at least as many colors as are to be mapped to the largest index.

Values in the scale clause must be in increasing order. Any value less than the first color is assigned the value of the first color. Any value greater than the last value is assigned the last color. Intermediate values are interpolated.

For example, assume the pctFemale column indicates what percentage of the group is female, and you want to map a group that is 100% female to red, 100% male to blue, and 50% each to gray. The colors statement for this is:

```
colors pctFemale, colors "blue" "gray" "red", scale 0 50 100;
```

The **buckets clause** is similar to the scale clause without interpolation. All values are rounded down to the highest value in the clause, and that exact color is used. Values less than the first value use the first color.

The syntax for the buckets clause is

```
buckets float float ...
```

The syntax and assignment of colors is the same as for the scale clause.

If, in the above example, you use the buckets clause instead of the scale clause, the statement is:

```
colors pctFemale, colors "blue" "gray" "red", buckets 0 50 100;
```

All values greater or equal to 100 are colored red. Values greater than or equal to 50, but less than 100, are gray. All remaining values is blue.

If a color variable is specified, but neither a scale clause nor a buckets clause is given, a default scale clause is used. The values are generated automatically, ranging from the minimum value to the maximum value in the data.

### The Legend Clause

The **legend** clause creates a legend of the colors. The legend clause syntax can be any of the following:

```
legend off
legend on
legend "string" "string" ...
legend label "string"
```

The **legend off** clause turns the legend off. The **legend on** clause turns the legend on. It can be omitted if other legend statements are included. Specifying only **legend on** generates the default legend.

The default legend includes a single label to the left (with the name of the field that is mapped to color), and a list of colored labels on the right (with values obtained from the scale clause or the buckets clause). To override the strings in the colored labels, specify the strings as shown:

```
legend "string" "string"
```

To override the label on the left, specify it following the word *label*. To eliminate this label, specify an empty string; that is:

```
legend label ""
```

By default, the color statement affects bars. To affect disks, begin the statement with **disk color**:

```
disk color pctFemale;
```

If no colors, scale, or buckets clause is given for disk colors, the disks inherit the clauses given for bars.

### Label Statement

You can specify a variable name and a color for labels to appear in front of the bars, at the base. By default, no labels appear. The color is a single color (unlike the bars and disks). For example, the following line displays the numeric predictability value in red at the base of each bar:

```
label predictability, color “red”;
```

### Message Statement

The message statement specifies the message displayed when the pointer is moved over an object or when an object is selected. The syntax is similar to that of the C **printf** statement. A sample message statement is

```
message "LHS: %s\NRHS: %s\npredictability/expected: %.2f",
             LHS, RHS, predictability/expected;
```

This could produce the following message:

```
LHS: milk
RHS: bread
predictability/expected: 2.00
```

The formats must match the type of data being used:

- Strings must use %s.
- Ints must use integer formats (such as %d).
- Floats and doubles must use floating point formats (such as %f).

For details of the **printf** format, see the printf (1) reference (man) page (type **`man printf`** at the shell prompt).

A special format type has been added to **printf**. If the percent sign is followed by a comma (for example, `%,f`), commas are inserted in the number for clarity. Currently, only the United States convention of d,ddd,ddd.dddd is supported, with the decimal point represented by a period, and commas separating every three places to the left of the decimal point. For example, if the above format were:

```
message "LHS: %s\nRHS: %s\npredictability/expected: %.2f",
      LHS, RHS, predictability/expected;
```

it would produce the message:

```
LHS: milk
RHS: bread
predictability/expected: 1,000.00
```

The $, *, h, l, ll, L, and n **printf** format options are not supported.

All values, including the format string, are expressions. Thus, if want to distinguish rules with predictability greater than twice the expected, you can use

```
message predictability > expected*2 ? "LHS: %s\nRHS:
      %s\npredictability/expected: HIGH" : "LHS: %s\nRHS:
      %s\npredictability/expected: LOW" , LHS, RHS;
```

This could produce the message

```
LHS: milk
RHS: bread
predictability/expected: LOW
```

or:

```
LHS: milk
RHS: cake
predictability/expected: HIGH
```

You could also achieve the same result with a single format string:

```
message "LHS: %s\nRHS: %s\npredictability/expected: %s",
   LHS, RHS, predictability > expected*2 ? "HIGH" : "LOW";
```

If no message is specified, a default message is used.

### Item Statement

An item statement describes the item names displayed along the LHS and RHS axes. An item statement has the form

```
item colors <colorLeft> <colorRight>;
```

The colors are absolute colors, like the label color. There is also a statement to turn on/off the item names:

```
item <off|on>;
```

Display axes may be customized using the syntax:

```
item labels <leftLabel> <rightLabel;
```

For example

```
item labels “LHS” “RHS”;
```

produces the same as the default found in the examples file */usr/lib/MineSet/ruleviz/examples/category.ruleviz.*

### Grid Statement

The grid statement describes the grid on which the rules are displayed. A grid statement has the form

```
grid color <color>;
```

or

```
grid <off|on>;
```

The color is a single color.

### Options

The options statement lets you fine-tune certain parameters of the display. When the view section is first entered, options are loaded from the defaults file */usr/lib/MineSet/ruleviz/view.ruleviz.options*. This file is searched for in the following directories, in the order listed:

- */usr/lib/MineSet/ruleviz*
- *~/.MineSet* (where ~ is your home directory)
- the current directory

The file is not required to be present.

Options specified directly in the configuration file override those in the defaults files. The syntax of the options statement is

```
options option, option, ...
```

The following options are available:

- bar label size
- hide bar label distance
- hide disk distance
- grid size
- item size
- hide item distance
- font

The following is a description of each option.

- `options bar label size` *float*

  Specifies the size of the labels in front of the bars. Larger values result in larger labels.

- `options hide bar label distance` *float*

  Specifies the distance at which the bar labels are not drawn. Smaller distances improve performance, but the labels might not be visible.

- `options hide disk distance` *float*

  Specifies the distance at which disks are not drawn. Smaller distances improve performance, but the disks might not be visible.

- `options grid size` *float*

  Specifies the width and depth of grid cells.

- `options item size` *float*

  Specifies the size of the items.

- `options hide item distance` *float*

  Specifies the distance at which the items are not drawn. Smaller distances improve performance, but the items might not be visible.

- `options font` *"fontName"*

  Specifies the font used for items and bar labels.

*Appendix G*

# Format of the Evidence Visualizer’s Data File

The purpose of this appendix is to describe the Evidence Visualizer’s input data file. This file is a textual representation of the evidence classifier. The data file is generated automatically through the Tool Manager. In some instances one may wish to edit this file in order to alter label, attribute, or value names.

The Evidence Visualizer requires a data file containing the label and attributes, along with weights and probabilities. These are used to create the graphics. It is output as a result of running the Evidence Inducer through the Tool Manager. The format of the data file is:

```
#MineSet 2.5

<type> "<label>" <L>
"<label1>" <weight1> <probability1>
"<label2>" <weight2> <probability2>
:
"<labelL>" <weightL> <probabilityL>

<M>

<type> "<attrib1>" <N1> <importance1>
"<value1_1>" <weight1_1_1> <prob1_1_1> ... <weight1_1_L> <prob1_1_L>
"<value1_2>" <weight1_2_1> <prob1_2_1> ... <weight1_2_L> <prob1_2_L>
:
"<value1_N1>" <weight1_N1_1> <prob1_N1_1> ... <weight1_N1_L> <prob1_N1_L>

<type> "<attrib2>" <N2> <importance2>
"<value2_1>" <weight2_1_1> <prob2_1_1> ... <weight2_1_L> <prob2_1_L>
"<value2_2>" <weight2_2_1> <prob2_2_1> ... <weight2_2_L> <prob2_2_L>
:
"<value2_N2>" <weight2_N2_1> <prob2_N2_1> ... <weight2_N2_L> <prob2_N2_L>

:
:
:
```

```
"<attribM>" <NM> <importanceM>
"<valueM_1>" <weightM_1_1> <probM_1> ... <weightM_1_L> <probM_1_L>
"<valueM_1>" <weightM_2_1> <probM_2_2> ... <weightM_2_L> <probM_2_L>
:
"<valueM_NM>" <weightN1_NM_1> <probM_NM_1> ... <weightM_NM_L> <probM_NM_L>

history {
:
:
}
```

Where *L* is the number of label values, *M* is the number of attributes, and *N* is the number of values or bins for attribute *i*. The <>'s indicate variables. The actual file has numbers or strings. A NULL is considered a unique value if it is present in an attribute. If NULLs exist for an attribute they always appear as the first value (i.e., the first line following the attribute header) and are represented by "?".

The `<type>` can be

- NOMINAL, which currently implies a string valued attribute (or an integer attribute which is used for the label).
- ENUM, which is used for attributes binned in Tool Manager.
- AUTO-ENUM, which is used for attributes that have been discretized automatically by the inducer. If a type is not present, AUTO-ENUM is assumed.

Lines beginning with # are comments (and ignored by the program).

An optional history section can be included at the end of the file. It is used by Tool Manager for drill-through. Without this section, drill-through is not possible (in the Evidence Visualizer or any other MineSet tool).

The *weights* are the number of records (or sum of weights) in the table with that particular attribute value (or range of values); hence, the sum of the weights for each attribute equals the total number of records in the table (unless record weighting was used). The *probability* is the number of weights for that attribute value divided by the total number of weights. If the data file was generated with *Laplace correction* turned on, the probability is only approximately the number of weights for that attribute value divided by the total number of weights (see “Refining the Inducer With Further Options” in Chapter 13). Thus, the probability value indicates the proportion of records with a particular label that have this attribute value instead of another value.

Data files must have a *.eviviz* extension. When starting the Evidence Visualizer, or when opening a file, you must specify the data file.

A sample Evidence Visualizer data file, */usr/lib/MineSet/eviviz/examples/cars.eviviz*, follows.

```
#MineSet 2.5
#automatically generated
NOMINAL "origin" 3
"Europe" 73 0.179803
"Japan" 79 0.194581
"US" 254 0.625616
6
AUTO_ENUM "mpg" 5 25.448
"?" 3 0.0410959 0 0 5 0.019685
"- 16.1" 0 0 0 0 87 0.34252
"16.1-21.05" 10 0.136986 5 0.0632911 77 0.30315
"21.05-30.95" 43 0.589041 28 0.35443 67 0.26378
"30.95+" 17 0.232877 46 0.582278 18 0.0708661
NOMINAL "cylinders" 5 29.1759
"8" 0 0 0 0 108 0.425197
"4" 66 0.90411 69 0.873418 72 0.283465
"6" 4 0.0547945 6 0.0759494 74 0.291339
"3" 0 0 4 0.0506329 0 0
"5" 3 0.0410959 0 0 0 0
AUTO_ENUM "horsepower" 4 22.3514
"?" 2 0.0273973 0 0 4 0.015748
"- 78.5" 40 0.547945 46 0.582278 25 0.0984252
"78.5-134" 31 0.424658 33 0.417722 131 0.515748
"134+" 0 0 0 0 94 0.370079
AUTO_ENUM "weightlbs" 4 28.5157
"- 2379.5" 43 0.589041 57 0.721519 30 0.11811
"2379.5-2959.5" 18 0.246575 22 0.278481 57 0.224409
"2959.5-3274" 9 0.123288 0 0 29 0.114173
"3274+" 3 0.0410959 0 0 138 0.543307
AUTO_ENUM "time_to_60" 3 10.0055
"- 13.45" 3 0.0410959 3 0.0379747 78 0.307087
"13.45-19.45" 52 0.712329 75 0.949367 162 0.637795
"19.45+" 18 0.246575 1 0.0126582 14 0.0551181
AUTO_ENUM "year" 1 2.84217e-14
"ignore" 73 1 79 1 254 1
```

Note that the sum of the probabilities corresponding to a particular label value for a given attribute always equals 1. Consider the attribute *weightlbs*, for label value US (the first one), we have .11811+.224409+.114173+.543307=1.0 . Also note that attributes *mpg* and *horsepower* have NULL values.

The eviviz datafile (**.eviviz*) also accommodates loss matrices and optionally included Laplace factor. The next example *.eviviz* file contains both of these.

```
MineSet 2.5
# MLC++ generated file for MineSet Evidence Visualizer.
NOMINAL “edibility” 2
“edible” 5 0.621212121212
“poisonous” 3 0.378787878788

TOTAL 8

LAPLACE yes 0

LOSS
10 0 20
10 10000 0


3

NOMINAL “cap-shape” 6 47.6129309656
“bell” 1 0.195652173913 0 0.0333333333333
“conical” 0 0.0217391304348 0 0.0333333333333
“convex” 2 0.369565217391 2 0.566666666667
“flat” 2 0.369565217391 0 0.0333333333333
“knobbed” 0 0.0217391304348 1 0.3
“sunken” 0 0.0217391304348 0 0.0333333333333

NOMINAL “cap-surface” 4 27.8397591211
“fibrous” 2 0.386363636364 0 0.0357142857143
“grooves” 0 0.0227272727273 0 0.0357142857143
“scaly” 1 0.204545454545 2 0.607142857143
“smooth” 2 0.386363636364 1 0.321428571429

NOMINAL “cap-color” 10 47.6129309656
“brown” 1 0.18 1 0.264705882353
“buff” 0 0.02 0 0.0294117647059
“cinnamon” 0 0.02 0 0.0294117647059
“gray” 0 0.02 1 0.264705882353
“green” 0 0.02 0 0.0294117647059
“pink” 1 0.18 0 0.0294117647059
“purple” 0 0.02 0 0.0294117647059
“red” 1 0.18 0 0.0294117647059
“white” 1 0.18 1 0.264705882353
“yellow” 1 0.18 0 0.0294117647059
```

The LaPlace matrix follows the form shown in the GUI (see the description in “Loss Matrices” in Chapter 10.)

*Appendix H*

# Creating Data and Configuration Files for the Decision Table Visualizer

The purpose of this appendix is to describe the Decision Table Visualizer's data and configuration files. The **.dtableviz* file contains a schema and optional history section, and the **.data* file contains the data. The format of these two files is almost exactly that described in Appendix A.

The Decision Table Visualizer's **.dtableviz* file must contain a schema of the form: some number of columns of type string or enum; followed by a float column containing the weight of records; followed by a vector column, indexed by an enum containing possible classes, and containing the proportion of the weight of records in each class. The **.dtableviz* and **.data* files are automatically generated by the Tool Manager, and you should not normally need to modify them.

There are two extra key-words that the schema in the **.dtableviz* file uses that are not present in other schemas. They are "auto", and "nominal". The Decision Table Visualizer must be able to differentiate between different types of enums. For example, enums that have been automatically rendered discrete by mining are handled differently in drill-through, than enums that have been binned by the user in Tool Manager. Hence the keyword "auto" is used to distinguish columns that have been binned by mining.

The label may be a binned column, or it may be string column. Either way it appears as an enum in the schema, so that the final probs[] column can be indexed by it. If the label is string valued, the "enum" keyword is predicated with "nominal" to distinguish it.

## Sample File

An example configuration file created from the adult dataset follows:

```
MineSet 2.5
input {
     file "adult-tmbin-dtab.dtableviz.data";
     enum string `hours_per_week_bin_k` {"- 20", "20-28", "28-36",
"36-44", "44-52", "52-60", "60+"};
     enum `hours_per_week_bin_k` `hours_per_week_bin`;
     auto enum string `gross_income_k` {"- 9598", "9598-14579",
"14579-24794.5", "24794.5-24806", "24806-29606", "29606-42049.5",
"42049.5-46306.5", "46306.5-64885", "64885+"};
     enum `gross_income_k` `gross_income`;
     auto enum string `final_weight_k` {"- 223033", "223033+"};
     enum `final_weight_k` `final_weight`;
     float `weight`;
     nominal enum string `label` {"Female  ", "Male    "};    # the
label values
     float `probs[]`[ enum `label` ]; # and probabilities
}
history {
:
:
}
```

In this example, the name of the data file is *adult-tmbin-dtab.dtableviz.data*. The first three columns are attributes from the data. The first one, hours_per_week_bin has been binned by the user using Tool Manager. The second two, gross_income, and final_weight were binned automatically by the mining. Note the use of the **auto** keyword in their enum definition. The fourth column gives the weight of records having the values given by the first three columns.

The last column, probs[], is a vector valued column which gives the probability of each class, computed by dividing the number of records for each class by the value in the weight column. The sum of the entries of this vector must add to 1. Note that the definition of the index label includes the keyword **nominal** to show that the class values are not numeric, and hence do not have an implied ordering. The **nominal** keyword would not be present had the label been a binned numeric attribute.

*Appendix I*

# Command-Line Interface to MIndUtil: Analytical Data Mining Algorithms

The first part of this appendix describes the MIndUtil program and its options. The second part lists and describes the general options for MIndUtil. The final part describes the specific modes available. The MIndUtil program comes with the server side of the MineSet images and is invoked automatically by DataMover on the server when working through Tool Manager. MIndUtil provides extra functionality not directly available from Tool Manager and may be easier to use in a batch environment (for example, when you use cron jobs).

## MIndUtil Invocation and Options

MIndUtil provides the MineSet inducers and additional mining utilities, such as discretization (binning). It also provides features for file conversions. In the following description, all examples assume the UNIX shell is *csh* or *tcsh*. Users of *sh* and *ksh* can transform `setenv ENV val` into `ENV=val; export ENV.`

MIndUtil is shorthand for one of two programs, MIndUtil_p and MIndUtil_s. MIndUtil_p is the multi-threaded version of the program, while MIndUtil_s is the single-threaded version. The number of threads spawned by MIndUtil_p is controlled by the NUM_THREADS option (see below for how to set options). In the invocation examples below, replace MIndUtil with whichever version of the program that you intend to use. The Tool Manager parallelization preference determines which version of the program Datamove invokes.

The syntax for invoking MIndUtil is:

```
MIndUtil [-s] [-o <optionfile>] [-O <option>=<value>]
```

where the **-s** option suppresses environment options (described below). The **-o** option allows reading options from an ASCII option specification file containing one `<option>=<value>` per line. By convention, MineSet uses the suffix *.classify-opt* for such option files. The **-O** option (uppercase) allows setting a specific option by following it with the option name, an equal sign, and the value. The **-o** and **-O** can be repeated multiple times. If an option is set more than once, the last time it is set determines its value. For example, if it is set through an option file and then set again through using the **-O** flag, the latter one determines its value.

Each option has a unique name; all option names are written in uppercase letters. If you want to set up the *.datamove* file to keep data and classifier option files on the server, the following lines must be in the *.datamove* file:

```
keep_data_files=yes
keep_classifier_options_files=yes
```

This ensures that the option specification files ending with the *.classify-opt* extension (consisting of the options passed to MIndUtil via the Tool Manager) are not erased from the server after you invoke inducers through Tool Manager.

### Example With MIndUtil Options

A typical file (*iris-dt.classify-opt*) might contain the following lines:

```
MODE=classify-and-error
LABEL=iris_type
ALGORITHM=decision-tree
DT_SPLIT_BY=normalized-mutual-info
DT_LBOUND_MIN_SPLIT=2
DT_PRUNING_FACTOR=0.7
DT_MAX_LEVEL=0
CLASSIFIER_NAME=iris-dt.class
VIZ_NAME=iris-dt.treeviz
HOLDOUT_PERCENT=0.666667
RANDOM_SEED=7258789
BACKFIT_TEST_SET=Yes
DISP_CONFUSION_MAT=No
DISP_LIFT_CURVE=No
```

Given a schema file (*iris.schema*, which references *iris.data*), you can run MIndUtil from the command line to induce a decision tree by using the options file as follows:

```
MIndUtil -o iris-dt.classify-opt -O FLAT_FILE=iris-dt.schema
```

This is exactly the way MIndUtil is invoked by DataMover.

Options in MIndUtil can be set through a hierarchy of levels. An option set at a higher level (see below) overrides any setting from a lower level. The levels are:

- *Hard-coded default*—Many options have a hard-coded default value. If the value is not overridden in any of the higher levels, the hard-coded default is used.
- *Environment option*—An environment variable can contain the option's value. You can set the environment variable with the same name as the option itself. For example,

  ```
  setenv FLAT_FILE iris-dt.schema
  ```

  sets the FLAT_FILE option to *iris.schema*.

  An environment variable takes precedence over hard-coded defaults. The command-line option **-s** suppresses environment variables.
- *Command-line options*—You can set specific options with `-O <option>=<value>`

  For example, to generate a decision tree from *iris.classify-opt*, set the pruning factor to 0, and set the minimum records in a split to 1, use:

  ```
  MIndUtil -o iris-dt.classify-opt \
           -O FLAT_FILE=iris-dt.schema\
           -O DT_PRUNING_FACTOR=0 \
           -O DT_LBOUND_MIN_SPLIT=1
  ```

  This induces a larger tree for the iris dataset. Command-line options take precedence over environment variables and hard-coded defaults.

  The order of command line arguments is important: Options to the right override earlier options to their left. Thus, the **-O** options override the values set in the *iris.classify-opt* file.
- *User input*—If an option is required but the option was not set using any of the above levels in the hierarchy, you are prompted for the option, and you can type a value.

  If you type **?**, a help string appears to explain the meaning of the option. User input has the highest precedence and given values override command line options, environment variables, and hard-coded defaults.

A special environment variable, called PROMPTLEVEL, determines when to prompt the user for an option. The variable has three possible values:

- *Required-only* prompts you for required options only. There are no prompts for options with a hard-coded default value. This is the lowest level prompting mode and the default.
- *Basic* prompts you for basic options (each option is hard-coded as basic or not), whether or not they have a default value. Some options are defined as "nuisance" (non-basic) options and are not prompted for by this mode. The purpose of this mode is to prompt for the most commonly used options.

  If the option has a default, you can change it to be a nuisance option by setting the option value to an exclamation mark ("!"). A nuisance option can be changed to a non-nuisance option by setting its value to be a question mark ("?"). For example, you can type:

  ```
  setenv PROMPTLEVEL basic
  MIndUtil -o iris-dt.classify-opt -O DT_MAX_LEVEL="?"
  ```

  You now are prompted for most options (non-nuisance) with defaults taken from *iris.classify-opt*. To accept the default, press Enter. Since FLAT_FILE is not defined in *iris.classify-opt* and is a required option, you are prompted for FLAT_FILE without a default. DT_MAX_LEVEL is a nuisance option, but setting it to a question mark specifies to prompt for it.
- *All* prompts you for all options, regardless of their nuisance setting.

When MIndUtil is executed from Tool Manager, all options except the schema filename are passed from the client through an options file *<file>.classify-opt*. On the server, the DataMover invokes MIndUtil with the options file and the appropriate schema file.

Tool Manager prepends any options it finds in *.mineset-classopt* on the client workstation. The file is searched first in the current directory, then in the home directory. The first one found is used.

When an option requires one of a given set of values (for instance, an enumerated option), a prefix of the desired option value can be used, and comparison is case-insensitive. If there are multiple values with the given prefix, the first one in the list is chosen. For example, the first option in MIndUtil is MODE, which takes on one of the following values: *classify-only, classify-and-error, estimate-error, learning-curve, discretize, auto-select, compute-importance, test-classifier, fit-data, mineset-to-mlc, mlc-to-mineset, score, upload-mlc, upload-mineset, visualize*. Setting the option to "c" selects classify-only. In scripts, use the full option name for future compatibility.

To facilitate repeat runs of a program under the same options, these can be saved in a file. The name of the file can be set through the environment variable *OPTIONS_FILE*. For example, if you run MIndUtil as

```
MIndUtil -o iris-dt.classify-opt \
         -O FLAT_FILE=iris-dt.schema\
         -O DT_MAX_LEVEL=1 \
         -O OPTIONS_FILE=foo.opt
```

the options will be saved in the file *foo.opt*, which you can edit and rerun by typing:

```
MIndUtil -o foo.opt
```

## General Options

MIndUtil is written using MLC++, the machine learning library in C++ (see http://www.sgi.com/Technology/mlc). More options can be used for those familiar with MLC++. Here are the important ones shared by many modes.

All filename specifications require the file suffix, except where detailed below.

- MODE is an enumerated option containing one of the following: *classify-only, classify-and-error, estimate-error, learning-curve, discretize, auto-select, compute-importance, test-classifier, assoc, cluster, fit-data, mineset-to-mlc, mlc-to-mineset, score, upload-mlc, upload-mineset, visualize*.
  - Classify-only builds a classifier using all the data.
  - Classify-and-error splits the data into a training set and a test set; a classifier is built from the training set and evaluated on the test set. If the classifier is a decision tree or option tree, the error estimates are added at the tree nodes for the visualization.
  - Estimate-error performs cross-validation to estimate the error of a classifier built using the induce option.
  - Learning-curve generates a learning curve.
  - Discretize allows discretizing continuous attributes.

  - Auto-select allows finding a set of important attributes together with prespecified attributes.
  - Compute-importance computes the importance of each attribute as if it were used individually with a prespecified set of attributes.
  - Test-classifier evaluates a previously induced classifier on new data. If a decision tree or option tree is used, the error estimates are added at the tree nodes for the visualization.
  - Assoc runs an association rules generator over the data and produces a file for the Rule Visualizer.
  - Cluster invokes the various modes of clustering that are available. It produces a file for the Cluster Visualizer.
  - Fit-data allows fitting new data to the structure of an existing classifier (backfitting).
  - MineSet-to-MLC and MLC-to-MineSet allow converting files from MLC++ format to MineSet format and vice versa.
  - Score generates a label values for each record, performing the same function as apply-classifier in the data-transformation panel of Tool Manager. This option is not supported and not documented further.
  - upload-MLC and upload-MineSet allow uploading a file in either MLC++ or MineSet format to a database. This option is not supported and not documented further. There may be loss of type information when files are uploaded, since MLC++ supports a smaller set of types than MineSet.
  - Visualize allows converting a classifier to a visualization.

  The details of each mode are described in the next section.

- FLAT_FILE is a string defining the MineSet schema file to use. The file specification must be complete (that is, with the *.schema* extension) and the file can be either a MineSet ASCII or binary file. See “Using MineSet With Existing Data Files” in Chapter 2 for a description of schema files.

- LOSS_FILE is the name of the loss matrix file. The loss file is optional. If it is supplied the format should be as follows:

  ```
  nodefault.
   ?,Iris-setosa: 10
   Iris-setosa,Iris-setosa: 0
   Iris-versicolor,Iris-setosa: 1
   Iris-virginica,Iris-setosa: 1
   ?,Iris-versicolor: 10
   Iris-setosa,Iris-versicolor: 1
   Iris-versicolor,Iris-versicolor: 0
   Iris-virginica,Iris-versicolor: 1
   ?,Iris-virginica: 1
   Iris-setosa,Iris-virginica: 1
   Iris-versicolor,Iris-virginica: 1
   Iris-virginica,Iris-virginica: 0
  endloss
  ```

  where each line other than the first and the last contain the predicted and the actual label values followed by a colon and the loss. The first line may be *default,* in which case all unspecified entries are zero on the diagonal and one off the diagonal. If *nodefault* is used, all matrix entries must be specified.

- LABEL is the name of the column or attribute that is to be used as the label whenever it is needed. The label name must be one of the columns in the schema file.

- WEIGHT is the name of the attribute that should determine the weight of each instance. It must be an integer or a floating point attribute and should be part of the schema.

- WEIGHT_IS_ATTRIBUTE is a Boolean option that determines whether the weight attribute can be used by the classifier as a regular attribute. In certain cases where the weight is a result of a stratified sample that is part of the experimental design, the classifier should not be given access to the weight column as it is not a property of the real-word entity.

- DISC_TYPE is an enumerated option taking on the value *uniform-weight, uniform-range,* or *entropy*. It determines the discretization mode: *uniform-weight* invokes uniform binning by record weights (ranges are not uniform); *uniform-range* invokes uniform binning by range, while *entropy* invokes automatic, nonuniform binning based on minimizing entropy (see "The Bin Columns Button" in Chapter 3). The default is *entropy.*

- DISC_MIN_SPLIT is an floating point value specifying the minimum weight of instances that must be in each bucket when discretization is being done. A value of zero automatically determines a value for DISC_MIN_SPLIT that grows slowly as the weight of the dataset grows.
- LOGLEVEL is an integer >= 0 defining the amount of logging information to print during the run. The default is zero. This option is hidden; you are not prompted for it.
- DRIBBLE is a Boolean operation defining whether to dribble output during processing in order to show progress. The default is TRUE. This option is hidden; you are not prompted for it.
- LINE_WIDTH is an integer > 1 defining the line width for the output. Automatic wrapping occurs to break words before this width. Wrapped lines begin with the WRAP_PREFIX string. The default line width is 79. This option is hidden; you are not prompted for it.

## Induction Modes

This section describes the options for induction modes: *classify-only, classify-and-error, estimate-error*, and *learning-curve*. The classify-only mode induces a classifier using the whole dataset. The classify-and-error mode induces a classifier on a portion of the dataset and tests it on the remainder of the dataset. The estimate-error mode performs cross-validation using the full dataset for a more robust error estimate. The learning-curve mode induces many classifiers using differently sized samples of the dataset to estimate the effect of sampling on the error rate.

All modes require specifying an ALGORITHM option, which determines the type of classifier or regressor to build. Note that in MIndUtil (unlike in the Tool Manager) regression models are treated as a type of classification model. The available values for the ALGORITHM option are *decision-tree*, *option-tree*, *evidence*, *decision-table*, and *regression-tree*. The following options are common to all algorithms:

- VIZ_NAME is a string defining the visualization name whenever appropriate. For the decision tree, option tree, and regression tree inducers, this option specifies the full name of the configuration file to be generated for the Tree Visualizer (recommended suffix is *.treeviz*). For the decision table inducer, this option specifies the full name of the configuration file to be generated for the Decision Table Visualizer (recommended suffix is *.dtableviz*). For the evidence inducer, this option specifies the full name of the Visualizer file (recommended suffix is *.eviviz*). For all inducers except the evidence inducer, a data file with an extra .data suffix will be generated automatically.

- CLASSIFIER_NAME is a string defining the name of the model which will be generated. This options is not applicable in the learning-curve mode.
- BACKFIT_TEST_SET is a Boolean option determining whether to backfit the test set data into the classifier's structure (see "Boosting: Accuracy is Sometimes Crucial" in Chapter 10).
- DISP_CONFUSION_MAT is a Boolean defining whether to display a confusion matrix (see "Confusion Matrices in Error Estimation" in Chapter 10). If this is set to yes, the option CONFUSION_MAT_SCATTERVIZ_NAME is needed, which determines the fully specified scatterviz file name (recommended suffix *.scatterviz).* This option is only applicable in the classify-and-error mode. It is not applicable to the regression-tree inducer.
- DISP_LIFT_CURVE is a Boolean defining whether to display a lift curve (see "Lift Curves in Error Estimation" in Chapter 10). If this is set to yes, the following options are needed: LIFT_CURVE_LABEL_VALUE, identifying the label value for which to generate the lift curve, and LIFT_CURVE_SCATTERVIZ_NAME, which determines the fully specified scatterviz file name (recommended suffix *.scatterviz*).This option is only applicable in the classify-and-error mode. It is not applicable to the regression-tree inducer
- DISP_ROI_CURVE is a Boolean defining whether to display a return-on-investment (ROI) curve (see "ROI Curves" in Chapter 11). If this is set to yes, the option ROI_CURVE_SCATTERVIZ_NAME is needed, which determines the fully specifies scatterviz file name (recommended suffix *.scatterviz)*. This option is only applicable in the classify-and-error mode. It is not applicable to the regression-tree inducer.
- BOOST_INDUCER is a Boolean defining whether to apply a boosting algorithm in conjunction with the Inducer to improve accuracy. (See "Boosting: Accuracy is Sometimes Crucial" in Chapter 10). There are a number of restrictions imposed if you turn on this option:
  - no visualization is produced (the VIZ_NAME option is ignored).
  - you cannot use the regression-tree inducer.
  - you MUST set BACKFIT_TEST_SET to FALSE (or you will get an error).
  - you MUST set EVI_AUTO_FEATURE_SELECTION to FALSE if running the evidence inducer.
- HOLDOUT_PERCENT is a floating point number between 0 and 1. It determines what ratio of the records to use as a training set. The rest are used as a test set. The default is two-thirds.
- RANDOM_SEED is an integer serving as the seed for the random-number generator used to split the records into training and test sets.

## Decision Tree Inducer Options

The following options are available for decision trees (ALGORITHM = decision-tree):

- DT_MAX_LEVEL, an integer >=0, limits the number of levels to grow the decision tree. The default of zero implies no limit.
- DT_PRUNING_FACTOR, a floating point number >=0, determines the pruning factor. Zero implies no pruning. The default is 0.7.
- DT_LBOUND_MIN_SPLIT, a float that provides a lower bound on the weight of records required to trickle down to at least two branches in a given node. No split will be made otherwise. The default is 2.
- DT_MIN_SPLIT_WEIGHT, a floating point number >=0, is the minimum ratio of training records divided by the number of classes that are required to trickle down to at least two branches in a given node. The default is 0.1. This option is not controllable from Tool Manager.
- DT_SPLIT_BY is an enumerated option taking one of the following values: *mutual-info*, *normalized-mutual-info*, *gain-ratio*. It specifies the evaluation criterion for choosing the attribute to split on at every node (see Chapter 11 for details). The default is normalized-mutual-info.
- DT_ADJUST_THRESHOLDS is a Boolean operator determining whether splits on continuous attributes have thresholds that are midpoints between two data points or whether the thresholds should be actual data values. The default is FALSE (that is, not to adjust the thresholds to data values). This option is not controllable from Tool Manager.

  This option is useful when you want to avoid splits on fractional values if attributes take on only integer values.

## Option Tree Inducer Options

The following options are available for the option tree inducer (ALGORITHM = option-tree) in addition to the options listed above for decision trees, which are all applicable to option trees too:

- ODT_ROOT_OPTIONS is an integer option determining the maximum number of splits at the root. The default is five.
- ODT_OPTION_CHANGE is an integer option determining the change in the maximum width allowed at every level of the tree. The default is -2. With the default ODT_OPTION_CHANGE of 5, option nodes will only be generated for the root (up to 5) and for the second level (up to 3). All levels below will have no option nodes.
- ODT_INIT_FITNESS is a floating point value which determines when to exclude attributes as options. When the inducer gives a fitness score to each attribute, it chooses the best attribute and other attributes that might also be good as options. The fitness ratio determines how good those other options must be. A factor value of *f* implies that to be considered an option, an attribute must rank at least(1- *f)*b* from the best scoring node, where *b* is the score for the best attribute. A fitness ratio of 1 picks all the attributes (so the limiting options described above are reached if there are attributes on which to split). A fitness ratio of 0 causes a regular decision tree to be created (no option nodes).

## Evidence Inducer Options

The following options are available for the evidence inducer (ALGORITHM= evidence):

- EVI_LAPLACE_CORRECTION is a Boolean determining whether to apply the Laplace correction (see Chapter 13). The default is false.
- EVI_LAPLACE_FACTOR specifies the correction factor to be applied during Laplace correction (see Chapter 13). The default is 0, which chooses a value automatically based on the data.
- EVI_AUTO_FEATURE_SELECTION is a Boolean determining whether to apply feature subset search along with the induction. (See Chapter 10). This may improve performance, but can be slow. You cannot set this option to TRUE if BOOST_INDUCER is set.
- EVI_FSS_BACKWARDS is a Boolean determining whether to run the feature subset search starting from the full set of columns. Doing so may perform better but is even slower than a regular feature subset search.

## Decision Table Inducer Options

The following options are available for the decision table inducer (ALGORITHM=decision-table)

- DTAB_X_NUM_ATTRS
- DTAB_X_ATTR_n
- DTAB_Y_NUM_ATTRS
- DTAB_Y_ATTR_n are options which specify the initial column mappings for the Decision Table Inducer. They should be used as follows:
  - set DTAB_X_NUM_ATTRS to the number of columns you wish to map to the X axis.
  - set DTAB_Y_NUM_ATTRS to the number of columns you wish to map to the Y axis.
  - columns are numbered starting with 0. For each column n on the X axis, set DTAB_X_ATTR_n to the name of the column.
  - For each column n on the Y axis, set DTAB_Y_ATTR_n to the name of the column.

Here is an example showing how to set the mappings for a sample file (*cars.data* from */usr/lib/MineSet/data*):

```
DTAB_X_NUM_ATTRS=1
DTAB_X_ATTR_0=time_to_sixty
DTAB_Y_NUM_ATTRS=0
```

This example maps a single column to the X axis and no columns to the Y axis.

- DTAB_FEATURE_SELECTION is a Boolean determining whether to automatically select column mappings for the induction. Setting this option is equivalent to using the Suggest then Go button in the Tool Manager. See Chapter 14, “Inducing and Visualizing the Decision Table.”
- DTAB_FEATURE_SEARCH is a Boolean determining whether to run a search over the space of column orderings to determine a better mapping ordering. If DTAB_FEATURE_SELECTION is also turned on, the feature selection process will be used to select the initial state for the search. Otherwise the search proceeds based on the column mappings. Checking the search box in Tool Manager and using the Suggest then the Go button will turn both this option and DTAB_FEATURE_SELECTION on.

- DTAB_MAX_NUM_ATTRS is an integer which limits the number of columns which may be suggested when DTAB_FEATURE_SELECTION is turned on. This option is ignored unless DTAB_FEATURE_SELECTION is turned on.
- DTAB_MAX_NUM_NODES is an integer which limits the total size of the decision table. See Chapter 14, “Inducing and Visualizing the Decision Table.”

### Regression Tree Inducer Options

The following options are available for the Regression Tree Inducer (ALGORITHM=regression-tree):

- RT_SPLIT_BY is an enumerated option which specifies the split criterion to use for regression tree generation. Allowable values are: *variance*, *absolute-deviation*, *normalized-variance*, and *normalized-absolute-deviation*.
- RT_SPLIT_LOWER_BOUND is a floating point option which specifies the minimum weight of instances allowed in one particular branch of a split.
- RT_PRUNING_METHOD is an enumerated option that specifies the pruning method to use for regression trees. This option currently allows only one value: cost_complexity.
- RT_PRUNING_FACTOR is a floating point option which specifies the number of standard errors worse than the minimum cost tree is acceptable. A value of 0 will return the minimum cost tree. This value may be any floating point number greater or equal to zero.
- RT_MAX_LEVELS is an integer option which limits the maximum depth of the tree. Set to zero to disable the depth limit.

## Estimate Error

If the MODE is estimate-error, cross-validation will be performed. The following options are available:

- CV_FOLDS is an integer determining the number of cross-validation folds. The default is 10. See Chapter 10 for details.
- CV_TIMES is an integer determining the number of times to repeat cross-validation. The default is 1. See Chapter 10 for details.

All other options are the same as for the induction modes.

## Learning Curve

If MODE is learning-curve, a learning curve is generated (see “Learning Curves in Error Estimation” in Chapter 10). All the options for the inducer modes are the same, plus the following:

- LEARN_CURVE_NUM_POINTS is an integer >0 that determines the number of points on the learning curve,
- LEARN_CURVE_RUNS_PER_POINT is an integer > 0 that determines how many times to run the inducer for each point on the learning curve. The more runs, the better the error estimate and the narrower the confidence interval.
- LEARN_CURVE_MIN_RECORDS is an integer that determines the minimum number of records, or what value for the x-axis should the learning curve start at. A value of -1 invokes an automatic heuristic.
- LEARN_CURVE_MAX_RECORDS is an integer that determines the maximum number of records, or what value for the x-axis should the learning curve end at. A value of -1 invokes an automatic heuristic.

## Clustering

If MODE is cluster, MIndUtil will invoke the clustering algorithm. Clustering behaves similarly to an inducer, except that no label is required (the LABEL option is ignored). Clustering uses the following options:

- CLUSTER_METHOD is an enumerated option taking on one of two values: *single*, or *iterative*. This option selects between the *single k-means* and *iterative k-means* clustering methods. (See Chapter 16, “Inducing and Visualizing Clustering.”).
- CLUSTER_NUM is an integer which specifies the number of clusters to find in the data. It is only used if CLUSTER_METHOD is set to single.
- CLUSTER_LOW is an integer which specifies the lower bound on the number of clusters to find in the data. It is only used if CLUSTER_METHOD is set to iterative.
- CLUSTER_HIGH is an integer which specifies the upper bound on the number of clusters to find in the data. It is only used if CLUSTER_METHOD is set to iterative.
- CLUSTER_CHOICE_POINT is a floating point number between 0.0 and 1.0 which is used to determine the final number of clusters. It is only used if CLUSTER_METHOD is set to *iterative*. For more details see Chapter 16, “Inducing and Visualizing Clustering.”

- CLUSTER_DISTANCE_TYPE is an enumerated option taking on one of two values: *euclidean* and *manhattan*. This option chooses the distance metric used by Clustering. See Chapter 16, "Inducing and Visualizing Clustering."
- CLUSTER_NUM_ITERATIONS is an integer which specifies the limit on the number of iterations the clustering algorithm may use. This is equivalent to the *max # iters* parameter in the Tool Manager. See Chapter 3, "The Tool Manager."
- RANDOM_SEED specifies a unique random initial starting position for the clustering algorithm. Different values of this option may produce different clusterings. See Chapter 16, "Inducing and Visualizing Clustering."
- CLASSIFIER_NAME is a string defining the name of the clustering model to be built. Suggested suffix: *.cluster*.
- VIZ_NAME is a string defining the name of the visualization files. This option should be set to the name of the file to generate for the Cluster Visualizer (suggested suffix: *.clusterviz*). A data file with an additional *.data* suffix will be automatically generated.

## Discretization

If MODE is discretize, discretization (binning) of attributes is performed and thresholds are determined. The following options are available:

- OUTPUT_NAME is the name of the file to contain the results.
- DISC_TRAIN_ONLY is a Boolean option that determines whether only the training set should be used for determining the discretization intervals. If a model is built and tested, it is important that the test set not be used for any part of the induction process. If this option is yes, HOLDOUT_PERCENT and RANDOM_SEED will be requested (see "Induction Modes" on page 690).
- ATTR_X, where X starts at 0 and increases. This defines the names of the attributes that you would like discretized.
- BINS_X, where X starts at 0 and increases. This specifies the number of bins to discretize ATTR_X into. Note that this is an upper bound and entropy binning may choose a lower number of bins. If the number of bins is zero, automatic heuristics are used.

**Example:** A discretization of two attributes, sepal width and petal length, according to label iris type, such that the number of bins is automatically determined, and only the training set portion of the dataset is used, can be done using the following options:

```
MODE=discretize
ATTR_0=sepal width
BINS_0=0
ATTR_1=petal length
BINS_1=0
DISC_TRAIN_ONLY=Yes
HOLDOUT_PERCENT=0.666667
RANDOM_SEED=7258789
DISC_TYPE=entropy
DISC_MIN_SPLIT=0
LABEL=iris type
WEIGHT=sepal length
WEIGHT_IS_ATTRIBUTE=Yes
OUTPUT_NAME=iris.disc
```

## Column Importance and Auto Selection

If MODE is auto-select or compute-importance, corresponding to the Find Importance and Compute Importance modes in the Tool Manager's Column Importance, the following options are available:

- OUTPUT_FILE is the name of the file to contain the results.
- ATTR_X, where X starts at 0 and increases. This defines the names of preselected attributes. All other attributes are candidates for auto-selection or are ranked if column importance is chosen.
- SELECT_N, an integer that determines the number of attributes to automatically select in auto-select mode, which corresponds to the non-Advanced mode and the advanced "find..." mode in column importance in the Tool Manager.

**Example:** To choose three attributes that can be used together with petal width to classify iris type, the following options can be used:

```
MODE=auto-select
LABEL=iris type
SELECT_N=3
ATTR_0=petal length
DISC_TYPE=entropy
DISC_MIN_SPLIT=0
OUTPUT_NAME=feature.fss
```

In this example, the discretization mode was entropy and the minimum number of instances in a bin was set to 0, indicating automatic MIN_SPLIT.

## Fit-Data

If the MODE is fit-data, the following options are available:

- TEST_CLASSIFIER_IN determines the input classifier, which usually contains a *.class* suffix.
- TEST_CLASSIFIER_OUT is the name of the generated classifier (the *.class* suffix is recommended).
- TEST_SHOW_VIZ is a Boolean option that determines if a visualization should also be generated. If the option's value is yes or true, VIZ_NAME must be supplied as the file name to output the visualization.

## MineSet-to-MLC, MLC-to-MineSet

These modes provide facilities to convert from MLC++ format to MineSet format and vice versa (see http://www.sgi.com/Technology/mlc). They can be used to convert UC Irvine (http://www.ics.uci.edu/~mlearn/MLRepository.html) formatted files or C4.5 formatted files, which are common in the machine learning community.

MineSet-to-MLC provides the following options:

- SPLIT_TRAIN_TEST, whether to split the data into two files: a training set and a test set.
- MLCFILE, the filename to export to. Suffixes of *.names*, *.data*, and *.test* are appended to this stem if SPLIT_TRAIN_TEST is true; otherwise, the suffixes are *.names* and *.all*. You can then run MLC++ inducers on these files, independent of MineSet.

MLC-to-MineSet provides the following options:

- DATAFILE, the file to import. If no suffix is given, it is assumed to be *.data*. It is recommended that you concatenate the training and test sets into a *.all* file and use that for importing.
- NAMESFILE, the names file describing the DATAFILE. A reasonable default is automatically suggested based on the DATAFILE option.
- OUTPUT_DATA, a MineSet output file. This should have a *.data* suffix.
- OUTPUT_SCHEMA, a MineSet schema file. This should have a *.schema* suffix.
- OUTPUT_LABEL, a string indicating what name to use for the label attribute.
- REMOVE_UNKNOWN_INST, a Boolean option indicating whether to remove records that have attributes with unknown values. The default is FALSE.

## Visualize

This mode lets you generate visualization files from classifiers. The following options are available:

- CLASSIFIER_NAME is the name of the classifier, including the file suffix.
- VIZ_NAME is a string defining the visualization name. For the decision tree inducer, this fully specified file name will be the name of the configuration file (recommended suffix is *.treeviz*) and a suffix of *.data* will be automatically added to the data file needed. For the evidence inducer, only one file name is needed (recommended suffix is *.eviviz*).

Note that the classifier does *not* contain error estimation information, so decision trees and option trees will just show the structure and distributions, not error estimates. You can use the test-classifier option within the apply-classifier option in ToolManager to generate a visualization that contains error estimates.

*Appendix J*

# Nulls in MineSet

Nulls represent unknown data. MineSet supports nulls in the data access tools, the mining tools, and the visualization tools. The purpose of this appendix is to give you a better understanding of the way MineSet handles nulls.

## Semantics of Nulls

Unknown data values are often represented as nulls in data sources. While it is possible to associate different semantics with nulls, the most common is that nulls represent missing or unknown values. For example, if a data record is made up of fields representing *firstname*, *middlename*, *lastname*, and if a person's *middlename* is not known, it can be represented by the null value.

Nulls can occur in data for a variety of reasons: They can occur naturally in data as a means of representing unknown data, or they can come about as the result of doing certain kinds of aggregations. For example, if there are no flights between San Francisco and MineSet City, a query such as "find the average flight time from San Francisco to MineSet City" yields a null value.

MineSet generally follows the semantics of relational databases when dealing with nulls, and treats them as unknown values.

Some databases, such as Oracle RDBMS, do not distinguish between null and empty strings. In such a case, it is not possible to distinguish between an unknown middle name and a person who does not have a middle name. On the other hand, Sybase RDBMS distinguishes between null and empty strings. Hence MineSet can distinguish empty and null strings when reading from Sybase, but not from Oracle.

## Representation of Nulls

In data files, as well as in the visual tools, nulls are represented by the string "?" (question mark). Thus, if Joe Miner's middle name is unknown, his name is represented in our example data file (having schema *firstname*, *middlename*, *lastname*) as:

```
Joe     ?     Miner
```

In general, the color gray is often associated with null values in the visualizations. The graphical representation of nulls varies from tool to tool. See the chapters on the individual tools for a discussion of how they represent them graphically.

## Operations on Nulls

Given that nulls represent unknown values, it becomes straightforward to give meaning to expressions involving nulls.

### Arithmetic Expressions

Arithmetic operations involving nulls always give a null result. For example:

(5 + ?) evaluates to ? (adding 5 to an unknown yields yet another unknown);

(6 / ?) evaluates to ?

### Boolean Expressions

In addition to taking on the values of TRUE and FALSE, Boolean variables can also be null. If a Boolean valued variable has a null (unknown) value, the result of combining it with another Boolean variable in an expression is also unknown, unless it is possible to determine just from the known value what the result is. In particular:

"? AND FALSE is FALSE", because FALSE ANDed with anything is always FALSE

"? AND TRUE is ?"

"? OR FALSE is ?"

"? OR TRUE is TRUE", because TRUE ORed with anything is always TRUE

"NOT ? is ?"

## Relational Operations

Relational operations (==, !=, <, >, <=, and >=) involving nulls always evaluate to null. Some particular cases worth emphasizing are:

"? == ? "evaluates to ?, not TRUE

"? != ?" evaluates to ?, not FALSE

"? != x"evaluates to ?, not FALSE

Given two unknown values, it is unknown whether the two are equal or unequal. This behavior can be confusing when using a search panel. For example, when searching for all values not equal to 0, nulls do not show up, yet neither do they show up when searching for values equal to 0. Because of this, search panels provide the ability to search explicitly for nulls. (Some search panels provide the option of treating nulls as zeros; see the individual tool discussions for more information.)

## Testing for Nulls

The function **isNull()** can determine whether or not a variable has the value null. For example:

**isNull(***X***)** evaluates to TRUE if variable *X* has the null value

**isNull(***X***)** evaluates to FALSE if variable *X* has a non-null value

## Aggregations in the Presence of Nulls

MineSet stays close to the semantics of SQL and relational databases when aggregating columns that might have null values. Thus, null values are ignored when computing SUM, AVG, MIN, MAX, and COUNT. This is best illustrated by an example. Consider a data file having records representing the number of pets a person has. The schema of this record is *name*, *num_pets*, and null (unknown) values are represented by "?".

| Name | NUM_PETS |
|---|---|
| Tesler | 3 |
| Rathmann | ? |
| Haber | 1 |
| Bhargava | 0 |
| Sangudi | ? |

Then,

SUM(NUM_PETS) = 4

COUNT(NUM_PETS) = 3 (and not 5, even though there are 5 rows of data)

AVG(NUM_PETS) = 1.33

MAX(NUM_PETS) = 3

MIN(NUM_PETS) = 0

In these aggregations, null values are basically ignored (note that the value 0 is different from ?, and is not ignored).

A special case of this is an aggregation where all the values being aggregated are themselves null. An even more specialized case is when there are no values being aggregated: for instance, when summing an empty column. In both these cases, the sum, average, min, and max are ?, while the count is 0.

## Sort Order for Nulls

In an ascending sorted sequence, null values always appear before non-null values. In a descending sorted sequence, null values always appear after non-null values.

## Bins and Arrays With Nulls

MineSet lets you bin numeric data into bins or discrete intervals. It also lets you (via the aggregation panel in the Tool Manager) create arrays on these bins. When a column of values is binned, all null values are put in a bin labeled "?". Such a bin label is always created, whether or not the data being binned has nulls in it. You have control over whether to use this bin for nulls in your application. You can do so by allowing arrays to ignore or keep bins for nulls by setting the desired option in the Tool Manager’s Preferences dialog. For example, if you know that the column being binned has no nulls, or you intend to study the data corresponding to non-null values only, you can choose to ignore the bin for nulls.

# Further Reading and Acknowledgments

Some datasets were taken from the UCI repository (Merz, C. J., and Murphy, P. M. (1996). UCI Repository of machine learning databases, Irvine, CA: University of California, Department of Information and Computer Science) found at http://www.ics.uci.edu/~mlearn/MLRepository.html

## Further Reading

Several papers describing the technology used in MineSet are available at http://mineset.sgi.com/tech

An excellent, non-technical introduction to data mining techniques is:

- Michael Berry and Gordon Linoff. *Data Mining Techniques*. New York: John Wiley & Sons, 1997. ISBN 0-471-17980-9. See http://www.data-miners.com/

A comparative study of data mining tools, including MineSet, was done by the Two Crows Corporation. It contains a good introduction to data mining.

- Two Crows Corporation. *Data Mining: Products, Applications & Technologies.* Ordering information is available at http://www.twocrows.com

A paper describing MLC++, the underlying analytical engine used in MineSet, is described in:

- Kohavi, R., Sommerfield, D., Dougherty, J., *Data Mining using MLC++, a Machine Learning Library in* C++. International Journal of Artificial Intelligence Tools, Vol. 6, No. 4, 1997, p. 537-566. See http://robotics.stanford.edu/users/ronnyk/

A general and easy-to-read introduction to machine learning is:

- Weiss, S. M., and C. A. Kulikowski. *Computer Systems that Learn*. San Mateo, CA: Morgan Kaufmann Publishers, Inc., 1991.

A general comparison of algorithms and descriptions is provided in:

- Taylor, C., D. Michie, and D. Spiegalhalter. *Machine Learning, Neural and Statistical Classification*. Paramount Publishing International, 1994.

An easy-to-read introduction to decision tree induction is:

- Quinlan, J. R. *C4.5: Programs for Machine Learning*. Los Altos, CA: Morgan Kaufmann Publishers, Inc., 1993.

An excellent book on decision trees from a statistical perspective is:

- Breiman, L., J. H. Friedman, R. A. Olshen, and C.J. Stone. *Classification and Regression Trees*. Wadsworth International Group, 1984.

A good edited volume of machine learning techniques is:

- Dietterich, T. G. and J. W. Shavlik (Eds). *Readings in Machine Learning*. Morgan Kaufmann Publishers, Inc., 1990.

A summary of accuracy estimation techniques is given in:

- Kohavi, R. *A study of cross-validation and bootstrap for accuracy estimation and model selection.* In Proceedings of the 14th International Joint Conference on Artificial Intelligence, edited by C. S. Mellish. Morgan Kaufmann Publishers, Inc., 1995. Available at
  http://robotics.stanford.edu/users/ronnyk/

The following paper describes the decision table metaphor:

- Kohavi, R., *The Power of Decision Tables.* In The European Conference on Machine Learning, 1995.

A good reference to a paper explaining that no classifier can be "best" is:

- Schaffer, C. *A conservation law for generalization performance.* In Machine Learning: Proceedings of the Eleventh International Conference, 259-265. Morgan Kaufmann Publishers, Inc., 1994. Available at
  http://wwwcs.hunter.cuny.edu/faculty/schaffer/papers/list.html

### Further Readings About Option Trees

MineSet uses an advanced version of the Option Trees described in:

- Ron Kohavi and Clayton Kunz. *Option Decision Trees with Majority Votes*. Machine Learning: Proceedings of the Fourteenth International Conference", Morgan Kaufmann Publishers, Inc., 1997. (See http://robotics.stanford.edu/users/ronnyk). The option trees used in MineSet average the predictions and do not simply vote them as described in this paper. Option Trees were first introduced by Wray Buntine in his thesis *A Theory of Learning Classification Rules*, 1992, School of Computing Science, University of Technology, Sydney.

### Further Readings About the Evidence Inducer

The following paper describes the wrapper method used to select the features for the Evidence Classifier:

- Kohavi, R., Sommerfield, D. (1995). *Feature Subset Selection Using the Wrapper Model: Overfitting and Dynamic Search Space Topology.* The First International Conference on Knowledge Discovery and Data Mining, pp. 192-197. Available at: http://robotics.stanford.edu/users/ronnyk/

An excellent introduction to the Evidence Classifier (Naive-Bayes) is:

- Kononenko, I. (1993). *Inductive and Bayesian Learning in Medical Diagnosis*. Applied Artificial Intelligence, pp. 7:317-337.

The following paper describes conditions under which the Evidence Inducer is optimal:

- Domingos, P., Pazzani, M., *Beyond Independence: Conditions for the Optimality of the Simple Bayes Classifier*. Machine Learning, Volume 29, No. 2/3, Nov/Dec 1997, pp. 103-130.

The following paper describes the use of the wrapper method in the Evidence Inducer:

- Kohavi, R., John, G., *Wrappers for Feature Subset Selection*. In Artificial Intelligence Journal, special issue on relevance, Vol. 97, Nos 1-2, pp. 273-324.

The following paper describes the Laplace correction option:

- Cestnik, B. (1990). *Estimating Probabilities: A Crucial Task in Machine Learning*. Proceedings of the Ninth European Conference on Artificial Intelligence, pp. 147-149.

The following paper describes the automatic Laplace correction used in MineSet:

- Kohavi R., Becker B., and Sommerfield D., *Improving Simple Bayes, European Conference on Machine Learning*, 1997 (poster). Available at http://robotics.stanford.edu/users/ronnyk/

The following paper describes the Evidence Classifier (Naive-Bayes):

- Langley, P., Iba, W., Thompson, K. (1992). *An Analysis of Bayesian Classifiers*. Proceedings of the Tenth National Conference on Artificial Intelligence, pp. 223-228. Available at http://www.isle.org/~langley/pubs.html

Simple Bayesian Classifier. To appear in *Lecture Notes in Computer Science*: *Issues in the Integration of Data Mining and Data Visualization*, Springer Verlag, 1998.

The following books describe the Evidence Classifier:

- Good, I. J. *The Estimation of Probabilities: An Essay on Modern Bayesian Methods*. MIT Press, 1965.
- Duda, R., Hart, P. *Pattern Classification and Scene Analysis*, Wiley, 1973.

The following paper shows that while the conditional independence assumption can be violated, the classification accuracy of the evidence classifier (called Simple Bayes in this paper) can be good:

- Domingos P., Pazzani M (1996). *Beyond Independence: Conditions for the Optimality of the Simple Bayesian Classifier*. Machine learning, Proceedings of the 13th International Conference (ICML ’96), pp. 105-112. Available at http://www.ics.uci.edu/~pedrod/

### Further Readings About the Splat Visualizer

The following paper describes and provides further references for the technical details of the Splat Visualizer.

- Becker, Barry G, *Volume Rendering for Relational Data,* to appear in Proceedings of Information Visualization '97, IEEE Computer Society Press, Los Alamitos CA, October 19-24, 1997.

The following paper explains how to use Gaussian splats for volume rendering.

- Westover, Lee, *Footprint Evaluation for Volume Rendering* in Proceedings of SIGGRAPH ‘90, Vol. 24, No. 4, pages 367-376)

## Acknowledgments

The iris database (described in Chapter 10, “MineSet Inducers and Classifiers”) was originally used in Fisher, R. A. 1936. The use of multiple measurements in taxonomic problems. *Annals of Eugenics* 7(1):179-188. It is a classical problem in many statistical texts.

The breast cancer database was obtained from Dr. William H. Wolberg, L. Mangasarian, and W. H. Wolberg. Cancer diagnosis via linear programming. *SIAM News* 23(5):1 & 18. University of Wisconsin Hospitals, Madison, September 1990.

The data for the mushroom sample file comes from: *Audubon Society Field Guide to North American Mushrooms*. New York: Alfred A. Knopf, 1981.

The data on congressional voting was taken from the *Congressional Quarterly Almanac, 98th Congress, 2nd session 1984, Volume XL*, Congressional Quarterly Inc.: Washington, D.C., 1985.

The adult dataset was derived from the US Census Bureau survey in 1994 (http://www.census.gov/ftp/pub/DES/www/welcome.html).

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