Comparing Three Computational Models of Affect

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Abstract. In aiming for behavioral fidelity, artificial intelligence cannot and no longer ignores the formalization of human affect. Affect modeling plays a vital role in faithfully simulating human emotion and in emotionally-evocative technology that aims at being real. This paper offers a short expose about three models concerning the generation and regulation of affect: CoMERG, EMA and I-PEFiC^{ADM}, which each in their own right are successfully applied in the agent and robot domain. We argue that the three models partly overlap and where distinct, they complement one another. We provide an analysis of the theoretical concepts, and provide a blueprint of an integration, which should result in a more precise representation of affect simulation in virtual humans.

Keywords: Affect modeling, Cognitive modeling, Virtual agents

1 Introduction

Over the last decade, a virtual explosion can be observed in the amount of novel computational models of affect. Nevertheless, current affect models in software agents are still simplifications compared to human affective complexity. Although many agents currently have the ability to show different emotions by means of facial expressions, it is quite difficult for them to show the right emotion at the right moment. In anticipation of richer interactions between user and agent, this paper explores the possibility to integrate a number of models that are sufficiently similar, while preserving their individual qualities. As a first step into that direction, we compared three models (CoMERG, EMA, and I-PEFiC^{ADM}) of agent affect-generation and affect-regulation (or coping).

We selected three models inspired by some of the most influential theories in the emotion domain to achieve more realistic affective behavior in agents. The theory of Emotion and Adaptation of Smith and Lazarus [12] was formalized by Gratch and Marsella [10] into *EMA*, a model to create agents that demonstrate and cope with (negative) affect. The emotion regulation theory of Gross [5] was used as inspiration by Bosse, Pontier, and Treur [2] to develop *CoMERG* (the Cognitive Model for Emotion Regulation based on Gross), which simulates the various emotion regulation strategies described by Gross. The concern-driven theory of Frijda [4] was used by Hoorn, Pontier, and Siddiqui [6] to design *I-PEFiC^{ADM}*, a model for building robots that can trade rational for affective choices. We consider these theories because of their adequate mechanisms, simplicity and coherence. Together, they (Frijda, Smith & Lazarus, Gross) cover a large part of emotion theory. All three were inspired by an appraisal model of emotion, which makes them well suited for integration. In addition, these models are already implemented as computational models, which makes it easier to integrate them. All three approaches point at important aspects of human affective behavior, but also miss out on something. CoMERG [2] and EMA [10] address the regulation of affective states, but EMA does not regulate positive affect. CoMERG, on the other hand, has no provisions for generating affect, and does not explicitly account for a causal interpretation of the world state. I-PEFiC^{ADM} [6] generates and balances affect but is mute about the different regulation mechanisms. Because the models are complementary to each other, it makes sense to integrate them.

As a first step, the present contribution attempts to align and contrast different affect models as they were derived from the original emotion theories[1]. We will point out what deficiencies should be overcome to build a better artifact for human-agent interaction and to gain more insight into human affective processes.

2 CoMERG, EMA, and I-PEFiC^{ADM}

2.1. CoMERG

According to Gross [5], humans use strategies to influence the level of emotional response to a given type of emotion; for instance, to prevent a person from having a too high or low response level.

In [2], Gross' theory was taken as a basis to develop the emotion regulation model CoMERG. This model, which consists of a set of difference equations combined with logical rules, can be used to simulate the dynamics of the various emotion regulation strategies described by Gross. CoMERG was incorporated into agents in a virtual storytelling application [1]. Following Gross' theory, CoMERG distinguishes five different emotion regulation strategies, which can be applied at different points in the process of emotion generation: *situation selection, situation modification, attentional deployment, cognitive change,* and *response modulation.*

[1] Note that the presented models embody a particular variant of an affect theory in that they have some unique properties that distinguish them from their original source. Many design choices underlying such models arise from the need to create a working computational system, a challenge the original theorists have never confronted.

2.2. Emotion & Adaption (EMA) Model

EMA is a computational model of the cognitive antecedents and consequences of emotions posited by appraisal theory, particularly as conceptualized by Smith and Lazarus [12]. A central tenet in cognitive appraisal theories is that appraisal and coping center around a person's *interpretation* of their relationship with the environment. This interpretation is constructed by cognitive processes, summarized by appraisal variables and altered by coping responses. To capture this process in computational terms, EMA maintains an explicit symbolic representation of the relationship between events and an agent's internal beliefs, desires and intentions, by building on AI planning to represent the physical relationship between events and their consequences, and BDI frameworks to represent the epistemic factors that underlie human (particularly social) activities.

Appraisal processes characterize this representation in terms of individual appraisal judgments, extending traditional AI concerns with utility and probability:

- Desirability: what is the utility (positive or negative) of the event
- Likelihood: how probable is the outcome of the event.
- Causal attribution: who deserves credit/blame.
- Controllability: can the outcome be altered by actions of the agent.
- Changeability: can the outcome change on its own.

Patterns of appraisal elicit emotional displays, but they also initiate coping processes to regulate the agent's cognitive response to the generated emotion. Coping strategies work in the reverse direction of appraisal, identifying plans, beliefs, desires or intentions to maintain or alter in order to reduce negative emotional appraisals:

- Planning: form an intention to perform some act
- Seek instrumental support: ask someone that controls outcome for help.
- Procrastination: wait for an external event to change the current circumstances.
- Denial: lower the perceived likelihood of an undesirable outcome.
- Mental disengagement: lower utility of desired state.
- Shift blame: shift responsibility for an action toward some other agent.

Strategies give input to the cognitive processes that actually execute these directives. For example, planful coping generates an intention to act, leading a planning system associated with EMA to generate and execute a valid plan to accomplish this act. Alternatively, coping strategies might abandon the goal, lower the goal's importance, or re-assess who is to blame.

EMA is a fully implemented model and has been applied to a number of systems that must simulate realistic human emotional responses. Several empirical studies have demonstrated EMA's effectiveness in modeling emotion [9].

2.3. I-PEFiC^{ADM}

Originally, the empirically validated framework for Perceiving and Experiencing Fictional Characters (PEFiC) described the receiver's reception of literature, theater, and movie characters [7]. Later versions were applied to the embodied-agent domain and supplemented with user interaction possibilities, resulting into the Interactive PEFiC model. I-PEFiC was then used to model affective behavior of robots as a module for Affective Decision Making was added to simulate irrational robot behavior, hence I-PEFiC^{ADM} [7].

The groundwork of I-PEFiC^{ADM} is formed by the cognitive process triplet of an encoding, a comparison, and a response phase. During *encoding*, the robot perceives the user and the situation the user is in. The features of the 'user in a situation' are indexed on four dimensions as a description of what someone is like or does. The robot attributes a level of *ethics* to the user, that is, the robot tries to figure whether the user's character is good or bad. *Aesthetics* is a level of beauty or ugliness that the robot perceives in the user. *Epistemics* is a measure for the realistic or unrealistic representations that the user conveys about him or herself. During the encoding, moreover, the robot looks at the user in terms of *affordances*. Certain aspects of the user may count as helpful or as an obstacle.

In the *comparison* phase, the user's features are appraised for *relevance* to robot goals (relevant or irrelevant) and *valence* to goals (positive or negative outcome expectancies). User features (e.g., intelligence) encoded as positive (e.g., 'helpful') may afford the facilitation of a desired robot goal. This instigates positive outcome expectancy. The comparison between the features of robot and user establishes a level of *similarity* (similar or dissimilar). The measures in the encode phase - mediated by relevance and valence in the comparison phase and moderated by similarity - determine the robot's responses.

In the *response* phase, the robot establishes the levels of *involvement* with and *distance* towards the user. Involvement and distance are two tendencies that occur in parallel and compensate one another [14]. In addition, the robot calculates a value for the so called *use intentions*, the willingness to employ the user again as a tool to achieve robot goals. Together with involvement and distance, the use intentions determine the overall satisfaction of the robot with its user.

Based on this level of *satisfaction*, the robot may decide to continue or stop the interaction and turn to another user. In the Affective Decision Making module [7], the robot makes a decision on the more rationally generated use intentions in unison with the more affectively generated involvement-distance trade-off. The action that promises the highest expected satisfaction during interaction is selected.

3 Triple Comparison

Fig. 1 depicts the similarities and differences between CoMERG, EMA, and I-PEFiC^{ADM}. Although explicitly mentioned in I-PEFiC^{ADM} alone, it is not hard to apply the encode-compare-respond phases to CoMERG and EMA. In the next sections, we offer a comparison of models, using Fig. 1 as our reference point.

3.1. Encode

According to CoMERG, people can select different *situations*, or modify the situation they are currently in, to regulate their emotions. In CoMERG the evaluation of how 'good' a certain situation is, is assumed to be given. In EMA, situations are appraised using the utility of state predicates about the situation and a causal interpretation of this situation. The agents can cope with these situations to change the person-environment-relationship, either by motivating changes to the interpretation of this relationship or by motivating actions that change the environment. I-PEFiC^{ADM} regards the user, agent, or character as part of a situation and that situation primes the features that are selected and how they are perceived.

Features in CoMERG are called aspects. According to CoMERG, a person can focus on one or another aspect (feature) of the world to regulate his or her emotions. In EMA, "current state predicates" in effect relate to those features considered in the subjectively construed situation. State predicates are statements about features of the environment which can be true or false. In I-PEFiC^{ADM}, features receive a certain weight according to frequency of occurrence, salience, or familiarity. Weights can change because of attentional shifts or situation changes.

The *appraisal domains* of I-PEFiC focus on characters. There is a host of evidence that for the judgment of fictional characters [7] and embodied agents [14], users classify features as good or bad, beautiful or ugly, realistic or unrealistic, and as aids or obstacles. According to EMA, on the other hand, agents perceive the world according to a causal interpretation of past and ongoing world events, including plans and intentions of self and others and past actions.

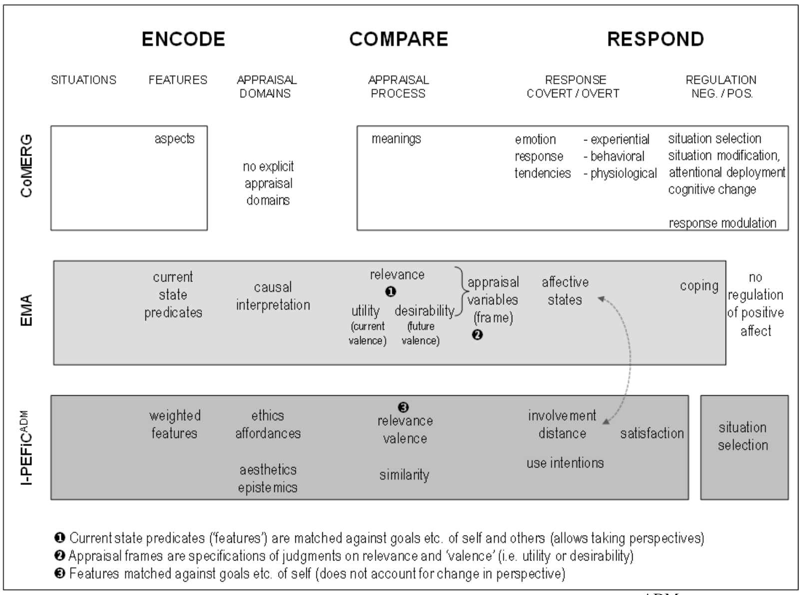

Fig. 1. Overview of CoMERG, EMA, and I-PEFiC^{ADM}

3.2. Compare

CoMERG refers to the *appraisal process* by "cognitive meanings." According to CoMERG, a person can perform the emotion regulation strategy 'cognitive change,' by attaching a different cognitive meaning to a situation. One type of cognitive change, *reappraisal*, means that an individual cognitively re-evaluates a potentially emotion-eliciting situation in terms that decrease its emotional impact [5]. In the view advocated by I-PEFiC^{ADM}, personal meaning is attached to a feature through relevance and valence. In a particular (imagined) situation, an object or feature may potentially benefit or harm someone's goals, beliefs, or concerns and as such, acquires 'meaning' ([4] cf. primary appraisal in [8]).

In EMA, this meaning is acquired through an appraisal process which is modeled in much detail. In this process, multiple appraisal frames are generated to allow for taking different perspectives. These appraisal frames are generated using many appraisal variables, which are taken from the theory of Smith & Lazarus, who call them the appraisal components, and Roseman, who calls them appraisal dimensions. Most of these appraisal variables could be mapped to relevance and valence used in I-PEFiC^{ADM}. According to EMA, relevance measures the significance of an event for the agent. Unlike Frijda, however, EMA equates significance with utility, which in Frijda's terms would be 'valence.' An event outcome is only deemed significant in EMA if it facilitates or inhibits a state predicate with non-zero utility. Valence is not explicitly mentioned in EMA although "utility" and "desirability" can be regarded as two instantiations of it.

Utility is a measure of the relative satisfaction from (or desirability of) environmental features. EMA represents preferences over environmental features as numeric utility over the truth-value of state predicates. Utilities may be either intrinsic (meaning that the agent assigns intrinsic worth to this environmental feature) or extrinsic (meaning that they inherit worth through their probabilistic contribution to an intrinsically valuable state feature). Utility, then, may be viewed as positive or negative outcome expectations about features in the current situation and is expressed in current state predicates (hence, 'current valence').

Desirability covers both a notion of intrinsic pleasantness and goal congruence (in Scherer's typology), as well as a measure of importance or relevance. It captures the appraised valence of an event with regard to an agent's preferences. An event is desirable, from some agent's perspective, if it facilitates a state to which the agent attributes positive utility or if it inhibits a state with negative utility. Like utility, desirability may be viewed as positive or negative outcome expectations but this time about features in the future situation ('future valence').

The explicit division in current and future states is what I-PEFiC^{ADM} is missing, as well as the possibility to change perspectives. EMA and I-PEFiC^{ADM} resemble each other in that causal interpretation of ongoing world events in terms of beliefs, desires, plans, and intentions in EMA is comprised in the beliefs, goals, and concerns that are checked for relevance and valence in I-PEFiC^{ADM}. However, EMA uses a number of variables, called appraisal frames, to cover the appraisal process, whereas in I-PEFiC^{ADM}, these appraisal frames appear to pertain to the more general concepts of relevance and valence. For example, urgency would be a clear-cut specification of relevance (cf. [4]) and ego involvement could be seen as a part of valence. However, EMA also uses some variables (such as causal attribution and coping potential) which are more related to the environment and less to the character, and which are somewhat broader than relevance and valence.

3.3. Respond

Fig. 1 exemplifies that in EMA, relevance of an event as well as utility and desirability (current / future valence) of features are mapped via an appraisal frame onto emotion instances of a particular category and intensity. These are called affective states. This may be seen as a covert response to the situation – an internal affective state that does not yet nor necessarily translate into overt actions. In I-PEFiC^{ADM}, affective states as such are not the focus but rather the involvement-distance trade-off, which is seen as the central process of engagement.

What comes closest to EMA's affective states are involvement and distance (Fig. 1, curved arrows). On this view, emotions emerge during the trade-off. For example, if a girl is asked for a date by a boy she loves, her involvement with him may be accompanied by happiness. When the boy looks at other girls on this date, the girl may still be involved with the boy but this time she feels challenged.

The involvement-distance trade-off could also count as the concretization of the emotion response tendencies that CoMERG hinges on. In CoMERG, these tendencies result in several responses: experiential, behavioral, and physiological. EMA and I-PEFiC^{ADM} are restricted to the experiential and behavioral domain. In EMA, affective states lead to coping behavior. For example, if your car makes strange noises, you might adopt emotion-focused coping (e.g., wishful thinking: tell yourself it is not that important and will probably stop by itself) which will inform the next decision; or you might adopt problem-focused coping to take a specific overt action to address the threat (e.g., have your car checked at the garage). In I-PEFiC^{ADM}, the combination of involvement, distance, and use intentions predicate the level of satisfaction (experiential), which feeds into affective decision making. This results into overt responses (behavior) such as kissing, kicking, or walking away.

CoMERG describes five *emotion regulation strategies* (see Sec. 2.1). Following Gross, CoMERG predicts that strategies that are performed earlier in the process of emotion generation are more effective to regulate one's emotions. EMA provides a more specific model which focuses (in much detail) on coping. Situation selection and situation modification are implemented in EMA via problem-focused coping strategies (i.e., take-action) and avoidance. Attentional deployment corresponds to EMA's strategies of seek/suppress information. Cognitive change corresponds to EMA's various emotion-directed strategies. EMA does not model suppression. I-PEFiC^{ADM} focuses on situation selection. Another difference is that CoMERG and I-PEFiC^{ADM} allow the regulation of affect by increasing, maintaining, or decreasing the positive or negative response, whereas EMA focuses on decreasing negative affect alone. In EMA, being overenthusiastic is left uncontrolled, whereas in CoMERG and I-PEFiC^{ADM}, positive affect can be down-regulated or compensated for. As a result, one can state that coping in EMA is one of the instantiations of emotion regulation in CoMERG.

For EMA, there must be an explicit causal connection between coping strategies and the emotions they are regulating whereas for CoMERG that is not a prerequisite. In CoMERG, people perform strategies to change their level of emotion, which are simply modeled via difference equations. EMA gives a more detailed and formal description of how emotion regulation works. For example, reappraisal as a general emotion regulation strategy in CoMERG is in EMA described in terms of a change in causal interpretation.

4 Integration

In our attempt to integrate the above models, we will adhere to the naming convention of 'features' instead of 'aspects' that the agent can detect in a situation because both EMA and I-PEFiC^{ADM} use that concept and it is interchangeable with 'aspects' in CoMERG. Only I-PEFiC^{ADM} explicitly mentions the appraisal domains that are important in perceiving features. Therefore, the agent will use ethics, affordances, aesthetics, and epistemics as the main domains through which features are funneled into the appraisal process.

CoMERG, EMA, and I-PEFiC^{ADM} all assume or elaborate an appraisal process. CoMERG is least explicit and the concept of 'meaning' can easily be attached to 'personal significance' and 'personal relevance' in both EMA and I-PEFiC^{ADM}. In EMA and I-PEFiC^{ADM}, relevance and valence play an active role, but EMA models the different manifestations rather than the general concepts. In unison, we will use the term relevance to indicate importance or meaning to (dynamic) personal goals, concerns, beliefs, intentions, plans, etc. and valence as (current) utility or (future) desirability of features in a situation. This may instantiate in the form of, for example, urgency as an aspect of relevance and likelihood or unexpectedness as an aspect of valence.

On the response side, EMA focuses on mood and emotions whereas I-PEFiC^{ADM} emphasizes the more general trends of involvement, distance, and use intentions. Yet, they are two sides of the coin that could be called 'affective states.' Emotions and moods may evolve from involvement-distance trade-offs and both the specific (e.g., happy emotions) and general experiential response (e.g., involvement) may be liable to regulation strategies.

CoMERG provides the most profound distinctions with respect to the type of responses (experiential, behavioral, and physiological) and the number of regulation strategies. However, in no way are these distinctions at odds with EMA or I-PEFiC^{ADM}. Coping is best worked out by EMA and situation selection by I-PEFiC^{ADM}, encompassing a module for affective decision making that on the basis of expected satisfaction chooses from several domain actions.

Fig. 2 shows a blueprint for the integration of CoMERG, EMA, and I-PEFiC^{ADM} into a framework for computerized affect generation and regulation. On the far left of the figure, we see a virtual agent. She can perform attentional deployment to weigh the features of her interaction partners. The agent develops state predicates about others in a certain context. Features receive indices for different appraisal domains. The observed other acquires personal meaning or significance for the agent because she compares their features with her personal goals, beliefs, and concerns. This establishes the relevance and valence of others to her goals and concerns. While relevance determines the intensity of affect, valence governs its direction. The agent can also look at others through the eyes of another agent.

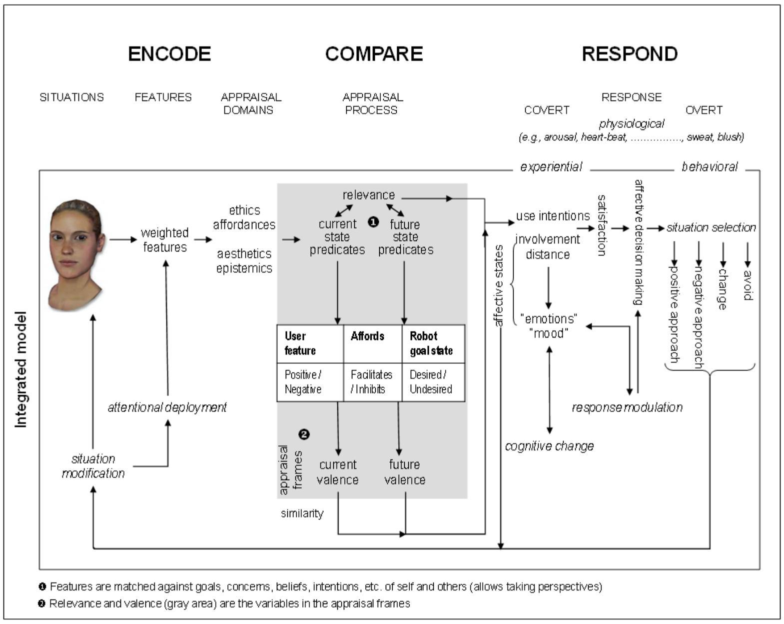

Fig. 2. Proposed integration of the three models

When the (initial) appraisal process is completed, the agent is ready to affectively respond. Relevance, current and future valence form an appraisal frame that feeds into her (un)willingness to 'use' someone for her purposes (e.g., having a conversation) and that helps her to trade friendship (involvement) for keeping her cool (distance). Inside, the agent will 'experience' several (perhaps ambiguous) emotions. On a physiological level, she may be aroused (e.g., increased heart-rate). All this is not visible to others yet; they are covert responses.

During affective decision making, the agent selects the option that promises the highest expected satisfaction. This may be accompanied by physiological reactions such as blushing and trembling. Response modulation may influence the affective decision making. The performed action leads to a new situation.

5 Conclusion

Various researchers from different fields have proposed formal models that describe the processes related to emotion elicitation and regulation (e.g., [2, 3, 7, 10]). For this reason, it is impossible to provide a complete comparison of existing models within one paper. Instead, the approach taken in this article was to select three of the more influential models, which share that they can be used to enhance believability of virtual characters: CoMERG, EMA, and I-PEFiC^{ADM}. The theories by which they were inspired cover most psychological literature in affect-related processes, including the works of Frijda [4], Lazarus [8], and Gross [5].

In this article, we have argued that each of the three approaches has its specific focus. For example, CoMERG covers a wide variety of emotion regulation strategies, whereas I-PEFiC^{ADM} provides an elaborated mechanism for encoding of different appraisal domains, which have empirically shown to be crucial in human-robot interaction. EMA on its turn contains very sophisticated mechanisms for both appraisal and coping, which have already proved their value in various applications. Because several of these features are complementary to each other, this paper explores the possibilities to integrate them into one combined model of affect for virtual humans. For a first attempt to implement this integrated model, see [11]. As a next step, it is planned to perform systematic user-tests in order to assess whether our integration indeed results in more human-like affective behavior than the three sub-models do separately.

References

1. Bosse, T., Pontier, M.A., Siddiqui, G.F., and Treur, J.: Incorporating Emotion Regulation into Virtual Stories. In: Pelachaud, C., Martin, J.C., Andre, E., Chollet, G., Karpouzis, K., and Pele, D. (eds.), Proc. of the Seventh Int. Conference on Intelligent Virtual Agents, IVA'07, pp. 339-347 (2007)
2. Bosse, T., Pontier, M.A., and Treur, J.: A Dynamical System Modelling Approach to Gross´ Model of Emotion Regulation. In: Lewis, R.L., Polk, T.A., and Laird, J.E. (eds.), Proc. of the 8th Int. Cf. on Cognitive Modeling, ICCM'07, pp. 187-192 (2007)
3. Breazeal, C.: Emotion and sociable humanoid robots. In E. Hudlika (Ed.), International Journal of Human Computer Interaction, Vol. 59, pp. 119–155 (2003)
4. Frijda, N. H.: The Emotions. New York: Cambridge University (1986)
5. Gross, J.J.: Emotion Regulation in Adulthood: Timing is Everything. Current directions in psychological science, Vol. 10(6), pp. 214-219 (2001)
6. Hoorn, J.F., Pontier, M.A., and Siddiqui, G.F.: When the user is instrumental to robot goals. First try: Agent uses agent. Proceedings of Web Intelligence and Intelligent Agent Technology 2008 (WI-IAT '08), Vol. 2, pp. 296-301 (2008)
7. Konijn, E.A., and Hoorn, J.F.: Some like it bad. Testing a model for perceiving and experiencing fictional characters. Media Psychology, Vol. 7(2), pp. 107-144 (2005)
8. Lazarus, R.S.: Emotion and Adaptation. New York: Oxford University (1991)
9. Mao, W., and Gratch, J.: Evaluating a computational model of social causality and responsibility. 5th Int. Joint Conference on Autonomous Agents and Multiagent Systems, Hakodate, Japan (2006)
10. Marsella, S., and Gratch, J.: EMA: A Model of Emotional Dynamics. Cognitive Systems Research, Vol. 10(1), pp. 70-90 (2009)
11. Pontier, M.A., and Siddiqui, G.F.: Silicon Coppélia: Integrating Three Affect-Related Models for Establishing Richer Agent Interaction. Proc. of Web Intelligence and Intelligent Agent Technology 2009 (WI-IAT '09), Vol. 2, pp.279-284 (2009)
12. Smith, C.A., and Lazarus, R.S.: Emotion and Adaptation. In L. A. Pervin (Ed.), Handbook of Personality: theory & research, pp. 609-637. NY: Guilford Press (1990)