Method for Live Production of Synthetic Lung Sounds in an Online Auscultation Simulator

オンライン聴診シミュレータの合成肺音のライブの製造方法

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Abstract

We are researching the development of an advanced auscultation simulator [1] that will provide for a dynamic examination with varying acoustic output based upon listening location [2], respiratory effort & phase. The simulator will be delivered online through web browsers and support a novel pedagogical approach [3]. Most extant lung sound samples are recorded at a single location and are rife with noise contamination [4], making them unsuitable. Thus, we employ synthetic lung & breath sounds with a clean acoustic profile so that numerous sounds can be mixed without degradation.

Two categories of sounds are created: vesicular and adventitious. Vesicular sounds [5] include normal breath, diminished breath, tracheal, & bronchovesicular sounds plus variants. Inspiratory & Expiratory vesicular sounds are selected separately and are combined to produce the desired rate & I:E ratio (Figure 1). Vesicular sounds form the basis of the respiratory loop and represent the 'base note' of the exam.

Adventitious sounds include varieties of fine crackles, course crackles, wheezes, rhonchi, pleural rubs, and squalks [6,7]. One or more sounds are mixed over vesicular sounds. The adventitious sounds must be very clean as there will already be audible airflow. Sounds are intended to be clear and distinct for the benefit of the learner. At a point within the defined respiratory loop, adventitious sounds are placed at will by a case author (Figure 2). The author may set the effective spatial area of the sounds in order to provide for localized findings which are a common finding in the pulmonary exam [8]. With control over the respiratory loop, spatial & temporal presentation, and access to a variety of synthetic lung sounds, a wide variety of clinical presentations may be created.

The next problem involves the live coordination & mixing of sounds during the simulation. A challenge because our simulator runs on web browsers, we employ the new open-source Web Audio API [9] to handle sound processing. The API uses Audio Nodes that provide for Sound Sources, Gain Nodes, Filters, Processors and Mixers (Figure 3). A Biquad Filter has many modes including Low Pass which can simulate the 200Hz attenuation of healthy lung tissue and vary the effect by listening locale. Other filters provide for phase, frequency, wave-shaping and environmental acoustic effects. Listening locale presentation is customized by manipulating Gain Nodes.

This method allows for a clean auscultation exam with clear and easily identifiable sounds which should aid in the learning process. Single sounds can be isolated during the dynamic exam as a teaching tool. Conversely, more complex and challenging presentations can be created.

One drawback to this approach is the expense and effort of creating the synthetic sounds, though once made they can be reused a great deal. When completed, our synthetic sounds will be posted on an open-source exchange [10]. Eventually, it may be possible to use high-quality processed lung recordings with this method.

Condition	Inspiration (sec)	Pause (sec)	Expiration (sec)	Pause (sec)	Breaths / min	I:E Ratio
normal	1.5	0.15	2.5	0.85	12	1.67
asthma	1.5	0.15	5.0	0.85	8	3.3
tachypnea	0.5	0.10	1.4	0.20	30	2.8
atelectasis	2.5	0.15	5.0	0.85	7	2

Figure 1 – Six fixed length vesicular sounds (3 insp / 3 exp) allow a variety of respiratory rates and I:E ratios.

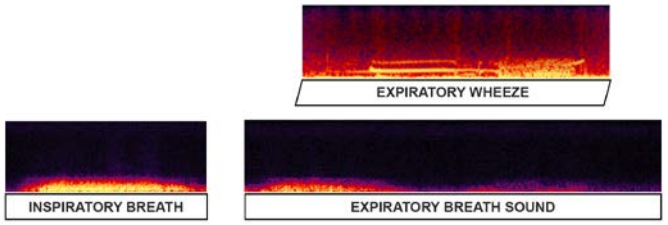

Figure 2 – Sound mixing employs vesicular sounds as a base which defines the respiratory loop. One or more synthetic adventitious sounds are then layered over. A synthetic wheeze would appear cleaner than this example.

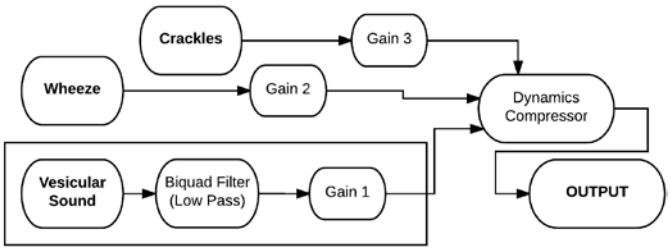

Figure 3 – Audio Nodes provide effects processing and gain control in real-time using the Web Audio API.

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