Sound Laboratory: A software-based system for interactive spatial sound synthesis

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The primary goal of the Sound Lab (SLAB) system is to provide an experimental platform to develop and validate advanced spatial auditory displays for aerospace applications. The aviation environment contains multiple channels of auditory and visual information that must be accessed under high stress, high workload conditions. Spatialized audio displays will increase the intelligibility of simultaneous verbal communications and auditory alerts in noisy conditions. The use of visual displays, such as those used for collision avoidance, may be improved by assigning some situational awareness and alerting functions to a spatial auditory display that allows the pilot's gaze to remain out the window. Spatialized audio displays could enhance realism and presence of virtual reality-based displays, such as those proposed for air traffic control. Efficient synthesis techniques and environmental modeling will also benefit from further research that specifies the computational fidelity required for perceptually viable displays. The SLAB software is being released under a free public license for non-commercial use. It is our hope that researchers will find it useful in conducting research in advanced audio displays and will also add their own modules to the software to provide additional functionality.

The SLAB system enables individual control of signal-processing parameters to conduct such studies (e.g., the number, fidelity, and positioning of sound sources and environmental reflections, system latency and update rate). SLAB also provides the basis for a low-cost, software-based system for dynamic synthesis of virtual audio over headphones that does not require an array of special-purpose, signal-processing hardware. SLAB features a modular, object-oriented design that provides the flexibility and extensibility needed to accommodate a wide range of experiments. It can readily take advantage of improvements in processing power without extensive software revisions.

The physical world to be rendered is comprised of a source, environment, and listener, as illustrated in Figure 1a. A source, characterized by its waveform, level, radiation pattern, size, and dynamic quantities including position and orientation, radiates into an environment. The source signal propagates through the environment and arrives at a listener characterized by a previously-measured head-related impulse response (HRIR) and interaural time delay (ITD), as well as a dynamically changing position and orientation. The SLAB signal flow (Figure 1b) implements these physical effects in an easily maintained, efficient architecture that consists of parallel signal paths from each rendered source to a listener's ears. Static effects along each path, such as materials reflection filtering are combined and implemented as an infinite impulse response (IIR) filter. A finite impulse response (FIR) filter implements dynamic effects like head-related impulse responses and the source radiation pattern.

One of the major implementation hurdles has been achieving adequate dynamic performance in the Windows environment. A preliminary estimate of the internal latency of the system (24 milliseconds) provided an encouraging assessment of the dynamic performance of SLAB, considering the inherent difficulties in managing low-latency Windows audio output. Informal listening tests indicate that the dynamic behavior of the system is both smooth and responsive. The smoothness is enhanced by the 120-Hz scenario update rate, as well as a parameter tracking method which produces rather high parameter update rates; i.e., time delays are updated at 44.1 kHz and the FIR filter coefficients are updated at 690 Hz. The responsiveness of the system is enhanced by the low latency of 24 ms. The scenario update rate, parameter update rates, and latency all compare favorably to other, more expensive virtual audio systems.