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SLAB: A SOFTWARE-BASED REAL-TIME VIRTUAL ACOUSTIC ENVIRONMENT RENDERING SYSTEM

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ABSTRACT

We will demo the features of Sound Lab (SLAB), a software-based real-time virtual acoustic environment (VAE) rendering system designed for use in the personal computer environment. SLAB is being developed as a tool for the study of spatial hearing.

1. INTRODUCTION

To enable a wide variety of psychoacoustic studies, SLAB provides extensive control over the VAE rendering process. The system features a modular, object-oriented design providing the flexibility and extensibility required for a short experiment development cycle. Because of its modularity, SLAB can support multiple rendering strategies without extensive software modifications. This demo provides an update to the work demonstrated and discussed in [1].

2. DESIGN OVERVIEW

In the following sections, a brief overview is provided of SLAB's acoustic environment, rendering process, and software architecture.

2.1. Acoustic Scenario Parameters

The acoustic scenario of a sound source radiating into an environment and heard by a listener can be specified by the parameters shown in Table 1.

SOURCE	ENVIRONMENT	LISTENER
Location	Speed of Sound	Location
(Implied Velocity)	Spreading Loss	(Implied Velocity)
Orientation	Air Absorption	Orientation
Sound Pressure Level	Surface Locations	HRTF
Waveform	Surface Boundaries	ITD
Radiation Pattern	Surface Reflection	
Source Radius	Surface Transmission	
	Late Reverberation	

Table 1. *Acoustic Scenario Parameters*.

Since SLAB is currently a work-in-progress, some of these characteristics have yet to be implemented, namely, radiation pattern, air absorption, surface transmission, and late reverberation.

The listener head-related transfer function (HRTF) database contains minimum-phase head-related impulse response (HRIR) pairs and interaural time delays (ITDs) at fixed azimuth and elevation increments. The azimuth and elevation increments can vary from one database to another.

2.2. Acoustic Scenario Rendering

The scenario parameters listed in Table 1 are implemented in an optimized, fixed signal flow architecture. Static effects, such as the surface reflection material filter, are combined and implemented using an infinite impulse response (IIR) filter. Dynamic effects, such as the head-related transfer function (HRTF) filter, are implemented using a finite impulse response (FIR) filter. To implement propagation delay and ITD effects, SLAB uses a linearly interpolated, two-times up-sampled delay line.

2.2.1. Scenario Update

Whenever a scenario parameter is updated, SLAB updates the signal processing parameters. A typical scenario update rate is 120Hz, although higher update rates are possible. Each scenario update, an image model computes the location of the sound source images. For each image, image-listener range and image arrival angle are computed. From these quantities, propagation delay, spherical spreading loss, and HRTF database interpolation weights are calculated.

2.2.2. DSP Parameter Update

Each scenario update results in a set of new DSP parameter targets (e.g. FIR filter tap targets, delay line index targets). The FIR filter coefficients are incremented towards their target parameters every 64 samples (1.45ms), while delay line indices are incremented every sample (22.7μs). This form of update is termed a "tracked parameter crossfade" and is discussed in more detail in [2].

2.3. Software Architecture

SLAB is a set of Windows libraries written in C++ following an object-oriented design paradigm. The decision to develop the system entirely in software was based on maintainability, developer resources, personal computer performance, and the persistence of standardized application programming interfaces (APIs). The SLAB software architecture is divided into three software layers:

SRAPI (SLAB Renderer API): The user of SLAB interacts with this layer. The SRAPI layer passes acoustic scenario parameters to the SLAB Renderer and provides high-level control of the SSRPC layer via a host or client/server interface.

SLAB Renderer: The SLAB Renderer layer performs acoustic scenario rendering. The SLAB Renderer is constructed such that any rendering strategy adhering to the same parameter interface can be easily substituted.

SSRPC (SLAB Sample Routing and Process Control): The SSRPC layer manages input and output objects, routs sound samples, and controls signal processing. It also provides interpolated delay line and DSP parameter tracking functionality.

This architecture allows for easy modification and extension for multiple rendering strategies. It is discussed in more detail in [3].

3. SPECIFICATIONS

The current system specifications are summarized in Table 2.

Scenario	
Room:	rectangular room, image model
Reflections:	6 first-order reflections
Direct Path FIR Taps:	128
Reflection FIR Taps:	32
Materials Filter:	first-order IIR filter
System Dynamics	
Sample Rate:	44.1 kHz
Update Rate:	120 Hz
Internal Latency:	24 ms
FIR Update:	every 64 samples (1.45ms)
Delay Line Update:	every sample (22.7µs)
Numerical Precision	
Sound Input/Output:	16-bit integer
Scenario:	double-precision floating-point
Signal Processing:	single-precision floating-point

Table 2. *Specifications*.

The number of sound sources is arbitrary, but depends on the scenario parameters and the available system resources.

4. THE DEMO

During the SLAB demo, the subject is outfitted with a pair of headphones equipped with an electromagnetic head-tracking sensor and placed in a simulated acoustic environment with one or more virtual sound sources. Prior to rendering, the subject may specify the wall material type for each of the six walls in a rectangular room. While rendering, the subject can move freely with six degrees of freedom in the virtual environment, enable and disable individual wall reflections, specify source trajectories, and change room dimensions.

5. CONCLUSIONS AND FUTURE DIRECTIONS

The goal of SLAB is to provide a software-based experimental platform with low-level control of a variety of signal-processing parameters for conducting psychoacoustic studies. To meet this goal, a modular, object-oriented design approach was taken. Future development includes enhancing the acoustic scenario with the addition of source radiation pattern, air absorption, surface transmission, and late reverberation models. To enable complex room geometries and higher order reflections, multiple processor systems and distributed architectures will be explored.

6. REFERENCES

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