

A Flexible 3D Sound System for Interactive Applications

Lalya Gaye

Future Applications Lab

Viktoria Institute

Box 620, SE-405 30, Gothenburg, Sweden

www.viktoria.se/fal

lalya.gaye@viktoria.se

ABSTRACT

We have developed a 3D sound system for headphones that allows real-time sound source and user displacement in a virtual acoustic environment. Because of a flexible design that uses different sets of pre-selected, physically modeled filters, the complexity level of the simulation can be chosen, making the system adaptable both to available CPU power and to application requirements. No extensive signal processing knowledge is required in order to select the appropriate simulation complexity. A preliminary evaluation involving 4 users showed that the system provides a satisfying localization of sounds and users (even with limited memory and CPU power) while also giving access to low-level control over simulation complexity.

Keywords

3D audio, virtual acoustic environment, interactive applications, physical modeling.

INTRODUCTION

Several virtual audio environments with real-time 3D interactive audio rendering have been constructed (e.g. [5]). Such systems may be used for a variety of applications: memory and comprehension improvement in video conferencing [2], interface enhancement for visually impaired users [6], video gaming, etc. However, most available systems are either too complicated, too application-specific, too expensive or offer too low performance for users who wish to develop interactive applications, but may not have extensive knowledge in Digital Signal Processing (DSP). The architecture of real-time 3D sound systems is generally rigid and only suited for specific kinds of applications, not allowing adaptation to available CPU power and to various types of applications.

Hence, we feel the need for low-cost, flexible 3D audio systems. Although low-cost 3D audio systems have been developed previously (e.g. [3]), the issue of flexibility in the architecture of real-time virtual acoustics environments systems has only recently been addressed [7, 8]. However, current research in this field has been targeted on spatial hearing researchers [8] or 3D audio

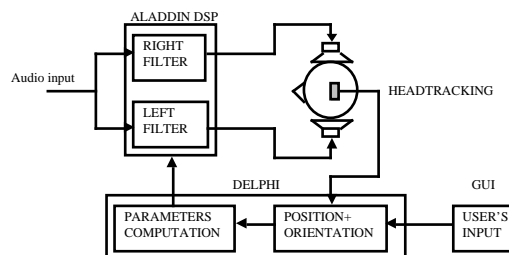


Figure 1: System overview

software developers [7], offering high-level control over the simulation processing. We propose a simple, low-cost and flexible 3D audio system that should be well suited to designers of interactive applications with an interested in audio. The flexibility of the system allows low-level control over the complexity of the simulation without requiring extensive DSP knowledge. Resource limited applications such as wearable or hand-held computing should particularly benefit from this kind of approach. Preliminary user experience with the system has shown promising results.

IMPLEMENTATION

Overview

The system consists of a headtracker, a signal-processing unit that converts a mono audio input into 3D sound, and a graphical user interface (see **Figure 1**). When listening to the output of the system through headphones, the user is placed inside a virtual room. The size of the room, the absorption coefficient of its walls and the level of complexity of the simulation model can be chosen prior to rendering. With the graphical user interface (GUI), the user can position and orient him/herself in real-time with 6 degrees of freedom (DOF), and also move the sound source to any position in the room. The headtracking device compensates for the actual movements of the user's head. The signal processing was developed using the DSP tool Aladdin Interactive DSP [1]. The parameter computation and the GUI were implemented in Delphi.

Flexible Signal Processing

The signal processing involved is based on a physical modeling of the interaction between the sound source, the acoustic environment and the listener's head and ears. The advantage of this approach is that it allows for various combinations of linear filters with different level of modeling complexity. In this way, one can adapt the system to the capabilities of the hardware and to the expected interactive applications while still using the

same 3D sound system. For instance, a simplified model can be used when developing an application that must use low processing power, while a more advanced model, giving a more realistic simulation, might be used if there is enough resources available. The designer will not need extensive DSP knowledge in order to select the appropriate model. Currently we have implemented four different simulation models, and new models can be created for specific applications.

User and Sound Source Displacements

In the current demonstration, user and source displacements in the virtual room can be controlled in real time, by adjusting scrollbars in a graphical interface. The interface controls the Cartesian coordinates and Euler angles that determine the user's position and orientation. The position of the sound source can be determined by using either Cartesian or head-related coordinates.

Headtracker

The system is completed with a low-cost device for tracking the user's head. This is based on standard magnetic tracking technology and is currently under development. The 6 DOF tracking information is used to compensate for the head's movement during interaction with the system. The output of the sensor and the user's input of his/her own localization in the virtual room are converted in real-time into user position and orientation data.

PRELIMINARY USER EXPERIENCE

We tested the system on four subjects, all with an interest in audio technology. General reactions to the system and the level of simulation control were enthusiastic. Unfortunately due to problems with the sensor, no headtracking could be used during the test. Subjects were asked to explore all other functions of the system, rating various aspects of it on a scale from 1 to 5, and to give general comments. The models are ranged with decreasing complexity: from model 1, which is the most advanced one, to model 4 which is the most basic.

| Model | 1 | 2 | 3 | 4 |
|----------------------------|------|------|------|------|
| Acoustic realism | 4.25 | 4.25 | 2.75 | 2.5 |
| Localization ability | 4 | 4.15 | 2.75 | 2.8 |
| Externalization | 4 | 4.25 | 3 | 2.5 |
| Front-back differentiation | 4.75 | 4.75 | 3 | 3.25 |
| Latency | 4.25 | 4.25 | 4.25 | 4.25 |

Table 1: System evaluation

As shown in **Table 1**, the users thought that the system provided a fairly high level of acoustic realism when using models 1 and 2, but was much less convincing

with models 3 and 4. The localization ability, the sense of externalization of sounds and the front-back differentiation were rated highly for the first two models and moderately for the two others. The latency of the simulation was satisfactory. The users appreciated that they did not need to concentrate on the details of the signal processing.

CONCLUSIONS AND FUTURE WORK

The preliminary results were promising, showing the system's success in providing low-level control over simulation complexity in flexible 3D audio environments. The current simulation models will be improved and others will be implemented. More extensive studies will be performed, using the system in the actual context of interactive applications development. We think that because of its flexibility, the system may be particularly suited to applications where resources are limited, such as hand-held or wearable computing.

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