SOUNDPIPES

A NEW WAY OF PATH SONIFICATION

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ABSTRACT

The processes of navigation and orientation in unfamiliar environments are mentally complex and difficult tasks. Many techniques have evolved to aid in this exploration, including perceptional skills (eg. landmarks) as well as technical tools (eg. maps). Both assist the sighted user in the navigation through complex environments. As auditory perception differs from vision, the tasks of navigation and orientation become more challenging. Some of the visual techniques can be adopted to the auditory world, but generally less information can be perceived through sound.

In this work, we first discuss several general approaches and techniques to aid in the exploration and navigation of virtual, auditory worlds. Along these techniques, we explicitly focus on the sonification of pathways and trails and introduce a new method for path sonification: *Soundpipes*. These soundpipes are easy to implement, but can greatly enhance the perception of auditory worlds as well as assist the user in the navigation and orientation within complex acoustic environments. The applications for the soundpipes approach are manifold and range from navigational aids for the blind to assistive tools for playing audio-only computer games.

1. INTRODUCTION

Travelling to other cities and countries is always an interesting activity and rich of new experiences and knowledge. Long ago, Goethe said that one can find no better education than through travelling [14]. The difficult part herein is the orientation within an unfamiliar environment. The chances of getting lost are quite high without any assistance or help. The local landmarks are unknown and we have difficulties to localize our position within this new environment. Although, the best way to get to know a new neighborhood is by pedestal exploration, nowadays many assistant techniques exist that aid in this investigation.

While exploring unfamiliar environments, we mentally create a map of the surrounding area which is constantly extended through new explorations. These maps are build by distinct checkpoints (landmarks), which are connected and form a graph. These points are later recognized and with it the connections to the neighboring points. Landmarks can be split in several groups which are classified regarding their range and visibility. The biggest landmarks, like towers and huge buildings, can be seen from large distances and build the most important group. Landmarks effectively help in the process of familiarization and assist us in locating ourselves within our mental model and the real environment. The same principle applies to virtual worlds as they are used in computer games. In the beginning of such computer games, the player is non only introduced into the story, but also in the games environment and his current position and status. Then the player moves around and explores the virtual world to gather enough information to form a mental representation of the environment.

The processes of navigation and orientation become even more difficult when auditory information only is present. In the last few years, audio-only computer games have received more and more attention. These games are similar to audio/visal games, except that all game information is presented through acoustics only. Often these games are developed for and by the visually impaired community, but feature ample potential for mobile (not necessarily cellphone only) gaming and other applications. The difficulty here is to effectively present the important information through sound. Many techniques have evolved to assist in the exploration of entertaining [13], [6] as well as scientific data sets [11], and can efficiently be used for the sonification and interaction with auditory worlds [8].

An often needed feature in virtual worlds is the possibility to easily get from point A to point B. While this task is not as difficult to design for visual systems, the adaptation to audio-only navigation poses several challenges. This paper discusses techniques for path sonification in virtual, auditory worlds, and develops a new method that allows an intuitive perception and provides guidance for acoustic pathways. The applications are manifold and range from assisting devices for real-world navigation as well as to techniques that aid on the play of auditory computer games.

The paper is organized as follows: The next section presents a brief introduction of navigation and orientation in virtual worlds with the focus on auditory environments. The section discusses both, perceptional skills as well as tools that have evolved to aid in this perception. The following sections explain the soundpipes approach for path sonification, with a theoretical part that is followed by a section with implementation details. Section 4 presents preliminary results and discusses the possibilities of the soundpipe technique. The paper concludes with a summary and a brief lookout for future improvements.

2. AUDITORY NAVIGATION

As already discussed in the previous section, the orientation and navigation within virtual, auditory worlds is a very challenging task. One of the main problems is the changing soundscape which can sound very different depending on the daytime and other aspects.

All auditory information that exists in our real world is the result of actions and certain physical processes. These sounds can have an informative, warning or distractive character, and assist us in acquiring environmental information. This information is used to judge the local surroundings regarding ongoing actions and the material it is constructed off. For the perception of acoustic information we use our ears that provide us not only with the sound, but also with the approximate location of the sounds origin. In ambiguous acoustic situations we slightly tilt our head to change the listening angle and to hear more precisely. Besides spatial information, we are able to derive environmental information from the sounds, like reverb and echoing, which helps to identify the size and the materials of our local environment. The physically correct generation and simulation of 3D sound and room acoustics is a challenging task and independent topic of research [7], [15]. For the programming of audio applications, many libraries and tools exist that are able to simulate 3D sound and room acoustics with good approximations [2], [1].

Some of the techniques, that are used for navigation and orientation in the visual world, can be adopted for navigating through auditory worlds. Objects and sources in auditory scenes can be utilized as landmarks, although acoustic landmarks are not as reliable as visual landmarks. Due to the often quickly changing soundscape, artificial beacons can be used to show the way. Examples which are often employed in virtual, auditory environments are an artificial compass and horizon.

Blind people have developed certain skills to use auditory information only for navigation and orientation in the real world. They rely on familiar sounds, slight vibrations and the personal experiences developed over the years. Many tools have been developed in the last decades to aid in the navigation and orientation of the blind community. Some of them use the global positioning system(GPS) in combination with virtual maps and a speech processor to identify the own location and to sonify interesting points nearby [4], [12].

Virtual, auditory worlds, and most auditory user interfaces, utilize beacons and earcons to convey information at and about interesting locations. Although, the rendering of 3D sounds and the simulation of room acoustics should be as physically accurate as possible, the representation of the scenery must not. Opposed to visual virtual worlds, auditory scenes have to be enhanced in order to provide more information. These enhancements have to be balanced between a proper scene sonification and an aesthetic scene perception. Tools like head-tracking and auditory cursors can greatly enhance the performance of the *interaction with sound* [8]. Many of these technologies are already employed in audio-only computer games which also utilize sonar and radar systems to gather information and to interact with objects [6], [10].

An often faced problem in virtual (and real) worlds is the need to get from point A to point B. One solution to this problem is path sonification that assists a user in following a pathway. The next section discusses such a system, which is intuitively to use and can easily be integrated in many existing applications.

3. SOUNDPIPES

In this section we describe and discuss our new approach to path sonification: **Soundpipes**. By definition, soundpipes are moving 3D point audio sources that travel along a predefined pathway. The number of moving sound sources, the time interval and the speed can be varied according to the needs of the application. As these beacons move along a pathway, the listener can determine their location and direction and follow it. At certain locations, additional beacons can be used to intersect the soundpipe and to sonify interesting points. A real-world comparison of this approach would be a public transportation system, which is similar in design and allow a user to travel from point A to point B. Figure 1 explains the principle and main idea of the soundpipes approach.

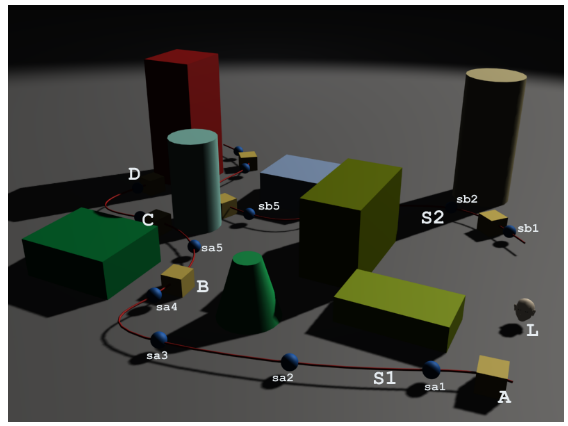


Figure 1: Soundpipes Principle

Figure 1 shows a simple scene with a listener **L** and two soundpipes **S1** and **S2**. Both are characterized through their sound sources **sa1..san** and **sb1..sbn**, which both use different beacons and sound settings. The listener, which travels from point **A** to point **B**, recognizes the sound sources that are representing the soundpipe, and can use them as guiding system to reach point **B**. In a final application, the soundpipes would be activated on request or triggered by an event. To catch the users attention and to simplify the recognition of the sounds direction, the sound sources are moving along the path with a given frequency and can additionally dither around their current location. All these parameters can easily be controlled by a program and adjusted to fit the needs of the users attention.

Besides the path sonification, the soundpipes approach allows the integration of additional ”stations” into the pathway. These stations, similar to the announcements of a subways station, can be used to sonify interesting locations along the soundpipe. Referring to the example in Figure 1, station **A** represents the starting point, station **B** the listeners destination, but he could also follow the soundpipe further till stations **C** or **D**.

A requirement for the use of soundpipes is the availability of a 3D sound system. While many systems support 3D sounds and HRTFs in hardware, there are still some quality issues. The best approach would be the use of personalized HRTFs, but these are difficult to measure and rarely available. But fortunately, research has shown that listeners can adopt to non-personalized HRTFs [5] and applications can be trained to accommodate the listeners hearing to adjust the given HRTFs [9]. Head-tracking devices additionally support the perception of 3D sound and can greatly enhance the immersion into the auditory world. While we use a research system from Polhemus, affordable consumer solutions are already available [3].

Many applications exist that would benefit from the soundpipes approach, ranging from real world navigation systems to audio-only computer games. Wherever a virtual, auditory world is used, this system can be easily integrated and be of great help in finding the proper direction and location. The next section discusses implementation details for our demonstration application.

3.1. Implementation

To evaluate the applicability of the soundpipes approach for navigational tasks in auditory environments, we have developed a small test application with two examples to demonstrate their efficiency. The program uses OpenAL and EAX 2.0 for the sound rendering and is developed under Windows. Figure 2 shows a screenshot of the program with one of the demo data sets loaded.

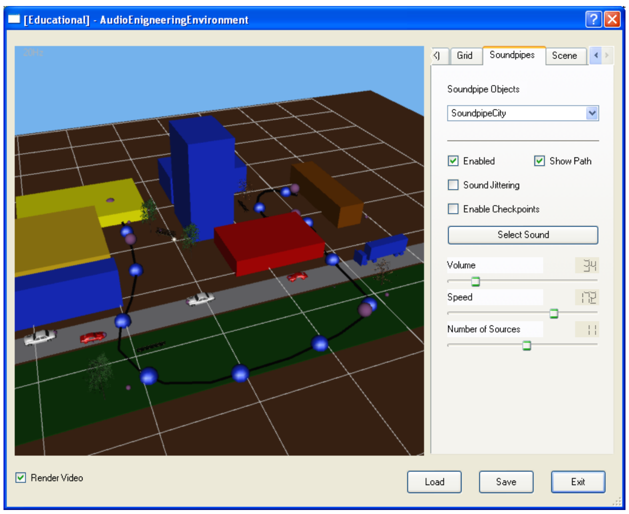


Figure 2: Soundpipes - Demo Application

For reasons of simplicity and to allow an easy interaction with the underlying idea, we have implemented a graphical user interface that allows to change several parameters as well as to visualize the scenery using computer graphics. The 3D environment as well as the soundpipes are modelled using 3D Studio MAX and imported as 3ds files and rendered using plain OpenGL shading. The soundpipes are represented as polygons and used as animation path for the moving sound sources. In the 3D representation these are drawn through thick GL_LINES. Our auditory scenes consist of several meshes, which are categorized as sound sources, EAX objects, the listener object, soundpipes and scenery (or background) objects. Each sound object represents a 3D sound source which can be individually defined. EAX objects represent different EAX environments and are simply used to acoustically enhance the scenery by providing environmental information. The soundpipes can be adjusted as discussed in the previous section and parameters like jittering, checkpoints, speed and moving direction are easy to change. A simple compass object aids in the determination of the scenes north direction.

The application uses the standard OpenAL listener as well as two cameras (listeners view and scene overview) for the graphical visualization. A gamepad (respective keyboard) is used as input device to control the virtual listener and headphones combined with a head-tracking system for intuitive listening. We found especially the head-tracking very helpful for precise listening and sound source localization. As consumer tracking devices are getting more affordable, these systems might soon not be restricted to research only and instead be beneficially integrated into many (not only audio-only) applications.

Figure 3: Soundpipes - Setup

Figure 3 shows a participant of the user study working with the program. Several tasks, including the localization and following of the soundpipes and stations have to be completed.

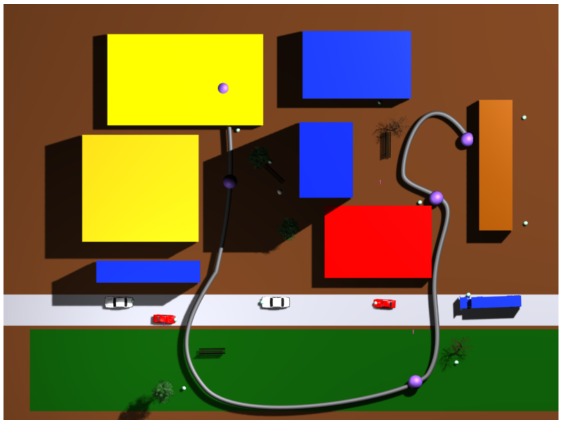
4. RESULTS

This sections discusses some of our results. With the developed program we performed a small user study to evaluate the functionality of the theory. For this task we designed two different scenarios: A city map with several different buildings and a partial implementation of an auditory adventure game. In both setups, the participants were asked to identify and find the soundpipes and to follow them in a predefined direction towards a certain goal. The evaluation of the user study included the analysis of the actual path, which was compared with the path of the soundpipe, as well as some general questions about the understanding and perception.

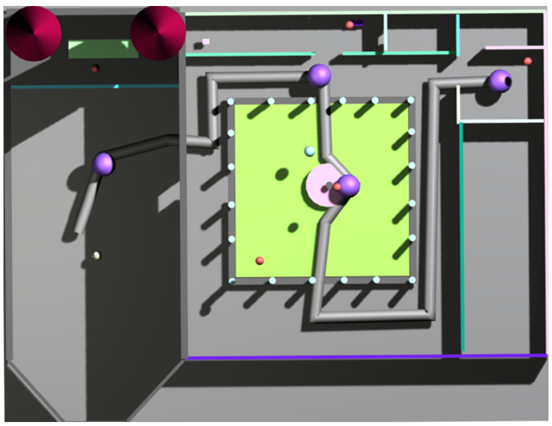
Figures 4(a) and 4(b) show the two demo data sets that were used in the evaluation. The city demo includes a railway station, office buildings, a cinema, a park, a school building and a post office. The scenery is full of natural sounds and the user is placed at random positions within the environment. Figure 4(a) shows a top view of this map. The soundpipe moves in the direction from A to D. As part of the user study, the participants had to complete three task:

1. Follow the path from point A to B.
2. Follow the path from point A and find the right exit C.
3. Find the soundpipe and follow it in the right direction to B.

The tasks for the other scenario were similar and the participants were also asked to identify and locate the soundpipes as well as their origin and orientation. Nearly everyone had no prior experiences with auditory environments and had also never played an audio-only computer game. The process of adopting to auditory navigation is difficult, but the majority found the soundpipes system very assisting and helpful in accomplishing the tasks. An important advantage was the integration of head-tracking, as it allowed an intuitive and very fast interaction with the auditory environment, which further enhanced the performance ion orientation



(a) City Navigation.



(b) Game Navigation.

Figure 4: Demo Data.

and navigation. Thus it was easy to find the soundpipes and their orientation, as well as to follow them. Difficulties were introduced by the use of non-individualized HRTFs for the 3D sound rendering. Several other studies have also noted that these are not sufficient to determine elevations and are also prone for front-to-back confusions.

5. CONCLUSION AND FUTURE WORK

We have presented a new technique for path sonification called *Soundpipes*. It is a simple, yet very effective technique for orientation and path visualization in 3D auditory environments. We have discussed the principles of this technique along with several implementation details and also evaluated the functionality using a short user study.

There are several possibilities for future improvements and testing. One points is to conduct a larger user study that compares the performance of sighted to the performance of visual impaired people. This could led into a very effective evaluation of the technique, and eventually a fine-tuning of the parameters to further increase the efficiency. These results can also be used to further develop and extend the principle of a soundpipe based path sonification.

Another point for future research is the integration of the soundpipe path sonification technique into an augmented audio system, which can be used for real world path sonification as well as for ”real world” audio games.

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