Experimenting with Sound Immersion in an Arts and Crafts Museum

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Abstract. Technical museums are goods targets for experimenting with sound immersion and soundscape authoring. This paper presents an immersive sound system emitting audio content. Experimentations were conducted with a wired, proof-of-concept prototype and two wireless devices. Our system takes into consideration the position of museum visitors as well as their orientation and visual vector. In contrast with other approaches, tracking and rendering are executed locally, in real-time by the visitor's device.

Keywords: museum, immersion, edutainment, sound spatialization, head-tracking, soundscape,

1 Introduction

The project described here is justified by a simple motivation: the machines exposed in the *Musée des Arts et Métiers* (MAM), one of the largest technical museums in France, are dumb. For many practical reasons, it is very difficult to run the machines for the public. As a consequence, visit in this type of museum turns out to be very close to a visit in a sculptures museum. The place granted to the sounds is indeed still marginal in museography and very few experiments are listed [2]. However, just like images, sounds are fundamental for learning [5]. The listening process is by nature slower compared with vision, but the reward is large since the sound is the vehicle of the human communication. The machines produce rich, complex and intense sounds often directly related with the function of the integrated mechanisms. Most machines in MAM have disappeared. However, there are strong chances that parts of the integrated mechanisms are still in use today (e.g. rods, vapor under pressure, rotating engines, etc.). The visitor could thus better comprehend the total operation of the machine exposed by associating already familiar and well known sounds. If, on the other hand, the sounds produced are not familiar, serendipity could be encouraged, with the unfamiliar acting as an element of surprise and stimulus for the visitor. Machines' sounds can be reproduced in a number of ways. In this paper, we concentrate on spatialization methods, where an auditory stimulus is positioned in virtual space defining its distance, localization (horizontal panoramic and elevation) and virtual acoustic simulation (reverberation) [3]. Real-time sound spatialization and audio augmentation is an accessible technology today, but its potential for the multimedia general public edutainment applications is much less studied in comparison with visual augmentation [8].

After a review of related audio augmented environments, we summarize the useful points for our project. We then describe two experimental devices. The first one was used in an experimental setting, collecting the orientation of the head of the listener. The second is based on a commercial audio guide, in pre-production phase. We then outline the future stages of the project.

2 Related Work

Today interactive museum guides have reached a high level of functionality including visitor tracking, navigation and interaction. Bederson [1] was among the first to develop an electronic museum guide prototype supporting visitor-driven interaction by utilizing portable mini-disc players and an infra-red (IR) system to allow museum visitors to explore an exhibition at their own pace. The early European HIPS projects that run from 1998 to 2000, made also use of the IR technology. The position of the visitor was calculated through the combination of infrared and an electronic compass data, those are sent to the central server that pushed the appropriate information on the visitors' terminal [4]. In the LISTEN project [9] the goal was to explore immersion in audio augmented environments by overlaying a virtual soundscape to the real environment users are exploring. A tracking transmitter/receiver, based on RF-burst signals in some cases and infrared cameras for others, is integrated on a wireless headphone. A central unit collects the data of each listener such as the absolute position and the orientation, then, appropriate auditory events are selected, spatialized in real time and sent to the user headphones as a binaural data. In *ec(h)o* [6], the visitor's location is tracked using RFID technology. Sounds played are related to the objects seen by the visitor. Holding an asymmetrically shaped wooden cube, the visitor interacts with the sound objects by movement and object-based gestures, in order to listen to related audio information. Finally, *Ambient Horn* [5] also explored the potential of augmented audio in outdoor environments, and more in particular during a visit in a woodland. The children moved to a location in which a local RF beacon was hidden, a sound was triggered and played through nearby wireless speakers while other implemented modules enabled the children to collect and exchange readings. The different architectures of ubiquitous virtual sound systems have also been discussed by Natkin et al. [7].

3 Recurrent matters and functional needs

Sound information besides spoken commentaries could give to the visitors a better understanding not only of the exposed machinery but also of the MAM history. According to their movement and their behavior, the visitors receive auditory messages which can be or not related to real visual objects. There is a strong relationship between the visitor’s body, the surrounding space, the time spent in a specific area and the sounds perceived. In all the previous works, the listener, the source, and the space are connected through a model of the scene, a sound map and a script which defines an interactive scenario. In order to define the script, virtual zones need to be mapped on the real space. The goal is to provide the listener with a good feeling of immersion while overlaying virtual elements inside a real scene. The coherence of an AR environment depends on the relationship between the real and virtual world and the visitor’s actions. Complex auditory information is prone to hierarchical relations. This means that the content of the virtual auditory scene has to be thought as a real soundscape composition in which the listener can distinguish clearly the different components.

4 Experimentation

Our research approach is different from previous approaches in a number of ways: first in the ability to capture the visitor's head orientation, and calculate his visual vector. Then, the system is fully distributed: it provides autonomous device for each user, meaning that the management of the system is achieved locally. As a consequence, the system can be used by a large number of simultaneous visitors.

4.1 System Description

Connected to a motion and orientation sensor embedded in a headphone, the proposed system creates a map of sound objects. It constantly analyzes the visual vector of a visitor, with the aim of delivering to him the appropriate composed sound according to the objects he/she is directed to. The distance separating the visitor with each object is also taken into account. The sound intensity emitted by the exposed object and delivered to the visitor is inversely proportional to this distance. The system also includes a 3D visual interface that reproduces the museum environment, the position of the museum visitors and the sound objects around them. This interface allows the management of the museum soundscape (e.g. enabling and disabling the emitted sounds, or updating their content and nature).

Initially, our approach consisted of conceiving and carrying out a virtual simulation of a sound-guided museum exhibition. This is done by creating a mini museum environment in the lab. Each exhibited object is associated with different types of audio contents: an audio description of the object, a reproduction of the ambient sound corresponding to the object and specific musical representations. Two execution modes are possible in the system. In the “virtual mode” the visitor's position and orientation is handled manually using the mouse and the keyboard. This mode can be used for visiting virtual museums and galleries on the net. The visitors may virtually displace themselves in the virtual environment, approach the objects and hear the audio content related to them. The “real mode” is used to visit museums in the real world. The visitor's position and orientation is handled, using a motion and orientation sensor. The visitor wears a stereo headset to which the sensor is attached (figure 2). The retrieval mechanism for the sounds object, the intensity and the orientation of each sound is based on the visitors' navigation in space which is continually updated while the visitors move through the exhibition.

Similarly, two separate graphical interfaces were attached to the system: A 3D interface and a 2D interface. The 3D interface shows the real time reproduction of the field of view of the visitor using the system. In case the virtual mode is selected the visitor can navigate using a pointing device attached to the system (mouse, keyboard, joystick). In the 2D interface, the system displays the map of the sound objects and the position and orientation of the visitor within the museum environment. Objects are represented as visual icons while the visitor is depicted as an icon and an arrow. The interface allows then, to activate or deactivate the sound emission of a specific object by simply clicking on its associated icon. Using a "Combo Box" containing speech, ambient sound, and beeps indicators, the type of audio content can be altered.

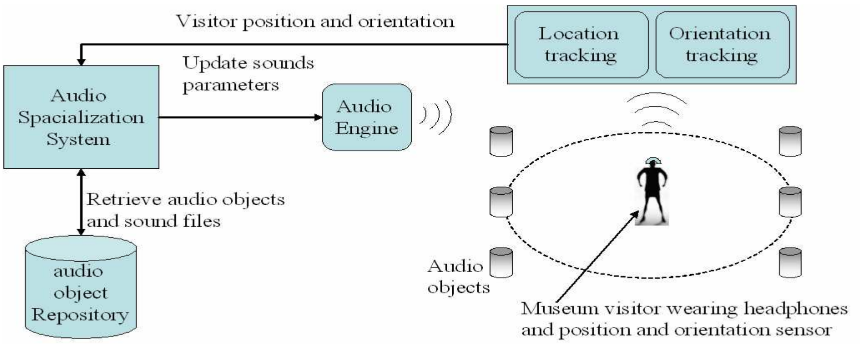

Figure 1: System architecture

4.2 Implementation

This system is developed using the Processing environment. The FMOD API is used for the sound spatialization. It is a multi-platform sound engine, free for non commercial use. For motion and orientation tracking, a Polhemus Patriot (PP) sensor was chosen for its reliability and low latency. Using this sensor was the first step for the validation of the sound spatialization functionality. However, its wired connection is not convenient for use in large spaces. After the initial validation using the wired PP, two other wireless tracking sensors were tested: the IMU 6 Degrees of Freedom produced by Sparkfun-elecronics company and the PERCIPIO headset developed by Eshkar &Falard industrie.

Before benchmarking the system, the audio contents had to be prepared. Though the system architecture supports an unlimited number of audio objects, the issue of an optimal perception of sounds was fundamental for our system. For this reason, a test on the maximum number of distinguishable audio objects placed in the same room has been performed. The participants had to stand in a fixed point and were acoustically surrounded by a changing number of audio objects. They only had the ability to turn their heads. Most of them have been able to simultaneously perceive up to six sounds. Beyond this number, locating audio objects and distinguishing them seemed to be difficult. For this reason, the system is provided with the ability of adjusting the maximum number of audio objects to be perceived.

Figure 2: (left): User holding the PP sensor, looking towards the objects of the real scene; his field of vision is reproduced on the interface. (right): Experimenting with the PERCIPIO headset at the CNAM museum

After choosing suitable audio samples for our experimentation, the sounds were normalized. The next step was the preparation of the experimentation environment. In a room of 4x4 meters, ten photos corresponding to audio objects were laid out on walls while the same scene was virtually reproduced in the 3D visual interface. The visitor wearing the stereo headset, on which the position and orientation sensor is fixed, is plunged into the immersive environment as soon as the audio objects are activated. His position and orientation is analyzed continuously, while the 3D characteristics of each activated sound are updated following the visitor' movements. When the visitor approaches an image, he can clearly distinguish the associated sounds according to his position and orientation (left or right). The visual field of the visitor is reproduced on the system visualization interface in real time (Figure 2). The latency between the change of user position and orientation and the update of audio content is estimated to 17 ms (milliseconds). This value is largely lower than the human auditory perception duration estimated to 50 ms (milliseconds). In addition, the visitor's head speed motion does not affect at all the auditory performance of the system.

At a second step another wireless tracking configuration was used: the industrial headset PERCIPIO. The head device is connected to a multimedia platform (PDA in our case) and can deliver personalized content according to the interests of the visitor. It is operational using the IR technology for indoor environments with 10cm precision and the GPS for outdoor environments with 5m precision. For calculating the head orientation, PERCIPIO makes use of a magnetic compass for the determination of the azimuth angle. Presently, we are evaluating PERCIPIO in terms of feasibility, latency, accuracy while we are also working on its integration as an orientation tracker in our sound spatialization system.

5 Conclusions and Future work

In this paper, an augmented audio reality system for experimenting sound immersion visiting a museum was presented. This system is specifically conceived and developed for technical museums, in which different types of machinery deprived of their sounds are exhibited. Our first experiments proved satisfactory in terms of performance of tracking-rendering couple. Future work will focus on the development of a binaural individual rendering. In addition, a high acoustic quality of the adaptive sound design related to the objects of the museum, will avoid auditory strain and bring the visitor in the best perceptive conditions. Hence, the next step is to record different sound of the machines. Then the prototype of an open composition will be created. Acquiring more data on the visitors behavior (speed, memory of trajectories, time spent in different locations) may improve this interactive scenario and the feeling of personal interactivity and immersion.

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