

# Immersive Audio-Augmented Environments

Gerhard Eckel

GMD – German National Research Center for Information Technology  
Institute for Media Communication – Virtual Environments Division  
Schloss Birlinghoven, D-53754 Sankt Augustin, Germany  
Phone: +49 2241 14 2968, Fax: +49 2241 14 2040  
Email: eckel@gmd.de, URL: <http://viswiz.gmd.de/~eckel>

## Abstract

In this paper we report about the LISTEN project, a research project funded by the European Commission in the context of the Information Society Technology (IST) program<sup>1</sup>. LISTEN, which started in January 2001, will provide users with intuitive access to personalized and situated audio information spaces while they naturally explore everyday environments. A new form of multi-sensory content is proposed to enhance the sensual impact of a broad spectrum of applications ranging from art installations to entertainment events. This is achieved by augmenting the physical environment through a dynamic soundscape, which users experience over motion-tracked wireless headphones. Immersive audio-augmented environments are created by combining high-definition spatial audio rendering technology with advanced user modeling methods. These allow for adapting the content to the users' individual spatial behavior. The project will produce several prototypes and a virtual-reality-based authoring tool. Technological innovations will be validated under laboratory conditions whilst the prototypes will be evaluated in public exhibitions.

## 1 Objectives

Intuitive access to information in everyday environments is becoming a central concern of new information society technologies. An important question is how established and well functioning everyday environments can be enhanced rather than replaced by virtual environments. Augmented or enhanced reality technologies address this issue but have concentrated so far on the visual sense and have mainly been used in industrial

---

<sup>1</sup> LISTEN – Augmenting everyday environments through interactive soundscapes, Fifth Framework Programme, Creating a user-friendly information society (IST), Contract no.: IST-1999-20646.

applications. Auditory augmentation of visually dominated everyday environments (such as exhibition spaces) is a new and very promising approach in creating user-friendly information systems, which are accessible to everybody. The complementarity between the visual and auditory sense is the basis for a new type of multi-sensory content, which will become feasible thanks to anticipated advances in auditory rendering, wireless tracking, and communication techniques in the context of this project.

LISTEN proposes a new type of information system for intuitive navigation of visually dominated exhibition spaces. Visitors are immersed in a dynamic virtual auditory scene that consistently augments the real space they are exploring. They wear motion-tracked wireless headphones for 3D spatial reproduction of the virtual auditory scene. A sophisticated auditory rendering process takes into account the current position and orientation of the visitor's head in order to seamlessly integrate the virtual scene with the real one. Speech, music and sound effects are dynamically arranged to form an individualized and situated soundscape offering exhibit-related information as well as creating context-specific atmospheres. The dynamic composition of the soundscape is personalized through each visitor's spatial behavior, the history of the visit, and interests or preferences either expressed explicitly by the visitor or inferred from the visitor's behavior. The proposed system is targeted at all kinds of exhibition applications ranging from art exhibitions to industrial fairs. Curators, artists, composers and sound designers will assist in the design of the system and help to shape this new form of multi-sensory content.

The evaluation of immersive audio-augmented environments will be carried out with virtual and physical prototypes. The virtual prototypes will be realized with an audio-visual surround-view display system using state-of-the-art virtual environment technology. The physical prototypes will be installed at 2 different sites. Out of the many possible applications of immersive audio-augmented environments, the validation will concentrate on museum applications. These are considered to be the most demanding in terms of perceptual quality, openness, flexibility and user-friendliness. The virtual prototypes will be used to develop different scenarios. Advanced audio guides will be developed showing the potential of the new form of content for pedagogical applications. In order to push the system to its limits, artistic applications will be realized as well in form of virtual prototypes. These prototypes will then be used to attract an internationally recognized artist who will be commissioned to realize the content for the main physical prototype. This physical prototype will be installed at the Kunstmuseum Bonn, a distinguished museum of modern art, and will be made accessible during several months in a public exhibition.

## **2 Innovation**

Innovation in the LISTEN project is located on two levels: the conceptual/artistic and the scientific/technological one. On the conceptual level, LISTEN proposes a new form of interaction between information and people. The strength of the approach lies in its simplicity and intuitiveness experienced by the end users: people just put on discreet wireless headphones and explore physical space by walking about. The space they explore becomes the actual interface to the information, which is presented in a virtual auditory space consistently augmenting the real space. In order to achieve the necessary consistency of augmentation, the LISTEN project proposes a set of innovations on the scientific/technological level, which are necessary to implement the conceptual vision of the project. Apart from the innovations in the areas of wireless motion tracking, binaural rendering, user modeling and adaptation, virtual prototyping and authoring, the main technological innovation of the project lies in the integration of new generation technologies.

### **2.1 Concept**

The idea of individual auditory augmentation of exhibition spaces is almost half a century old by now. Early audio guides used taped explanations about the artwork displayed in an exhibition. Visitors were wearing headphones and had to carry the playback device. They were also constrained to follow a particular path through the exhibition. This path was defined by the sequence of explanations stored on the tape, which allowed for linear access only. Apart from controlling the playback level, pausing the playback and eventually rewinding the tape, visitors could not interact with the presentation. Nowadays, audio guides use random access audio storage technologies (e.g. RAM, CD, MD, or CDROM based) allowing the visitors to enter exhibit specific codes to recall corresponding audio presentations. This simple and pragmatic solution is used by nearly all audio guide services currently offered by almost all big museums. Other types of audio guides were developed when wireless headphone technology became available in the eighties. Induction and infrared-based techniques were used to create zones around exhibits where visitors could hear audio clips repeated in loops. The main drawback of this presentation technique is that visitors will typically not arrive at the start of a loop and therefore hear the end before the beginning. The timing of the audio clips is not individually controllable but shared by all visitors. The main advantage of the wireless technology is that the users don't need to carry any playback device and that they can interact with the information by naturally walking through the exhibition spaces. They create their individual soundscape by freely moving from one zone to the another – and it is this feature which is of central importance to the LISTEN project.

### 2.1.1 Audio Guide

With LISTEN we generalize the audio guide concept by conceiving an adaptive and personalized spatial audio information system. This generalization is motivated by the conviction that the time of auditory user interfaces, especially in form of audio-augmented environments, has finally arrived. What prevented the realization of immersive audio-augmented environments in the past, was the lack of the most important requirement for advanced auditory interfaces: the availability of a spatial audio technology refined enough to make full use of the human sense of spatial hearing. Such technology (i.e. affordable wireless wide-area high-definition motion tracking combined with advanced binaural rendering and wireless digital audio transmission) only becomes feasible now and will be developed further in the context of this project. With this new technology all the features known from traditional audio guide systems can be emulated and - more importantly - a revolutionary set of new features for the design of interactive soundscapes is created.

The *key idea* of the LISTEN concept is to place the notion of space – of visual, auditory and imaginary space and their relationships – at the center of the design. By moving through real space, users automatically navigate an attached acoustic information space designed as a complement or extension of the real space. Virtual acoustic landmarks will play an equally important role than the visual ones for the orientation of the users in this augmented environment. Acoustic labels can be attached to visual objects. The particularities of auditory and visual memory can be combined to create new forms of non-linear audio-visual narratives. Objects can acoustically address the visitors when he or she passed them, thus providing exhibit-related information and calling for attention. Objects not in the field of vision can gain the attention of visitors through localized acoustic cues. Spatial regions can be provided with particular acoustic ambiances creating atmospheres and contexts for the visual perception of objects. Music and sound effects can be used to create an individualized sound track along the freely chosen path through an exhibition. The concrete visual space may be overlaid with an abstract auditory space, which proposes an alternative spatial structure. This could be realized by permeable “acoustic walls”, which invisibly separate zones in a visually continuous space. Along these borders room acoustic signatures could change, thus creating different acoustic spaces in one visual space. Spatial perception and navigation is one of the best-developed abilities of human beings and is therefore one of the most solid grounds an intuitive human-machine interface could be based on.

### **2.1.2 Immersive Audio-Augmented Environment**

With the immersive audio-augmented environment, LISTEN defines a new format of interactive audio content. Rather than a predetermined, pre-recorded audio program, listeners are offered a personalized audio environment, based on their interaction with the real space. The enhanced audio format can provide deepening layers of information, giving increasing levels of involvement. It will allow the visitors to find their own level of engagement with an exhibition. The depth of experience may vary giving each person the chance to find his or her own level or area of comfort and interest. These adaptive features of the LISTEN system are based on advanced user modeling methods, which allow extracting certain preferences from the user's spatial behavior. User modeling also allows avoiding redundancies in the presentation of audio information. The user model will keep track of each user's visit history and adapt the presented information with respect to what the user has already experienced. This will avoid repetition of information where it is not explicitly desired by the user and communicated to the system with a simple remote control unit. By these means, LISTEN provides enhanced, interactive sound tailored to the interests and experiences of the individual visitor and to a variety of exhibit types. These will range from art exhibitions in museums to gallery installations and from scientific conferences to industrial fairs or marketing events.

### **2.2 Technology**

Innovation on the scientific/technological level is concentrated in 4 areas: (1) motion tracking, (2) auditory rendering, (3) user and world modeling, and (4) authoring and simulation. Significant advances of the state of the art in the 4 areas are necessary to realize the LISTEN concept. Apart from the innovation in the individual areas, LISTEN proposes an integration of new generation technologies in an original way. Only the combination of large-area high-definition wireless motion tracking with advanced binaural rendering and wireless high-quality digital audio transmission provides for the degree of auditory immersion necessary to create convincing audio-augmented environments. Only the combination of novel user modeling techniques with advanced virtual-reality-based world modeling, authoring and simulation techniques can provide the basis for producing and experiencing a new form of content: the immersive audio-augmented environment. The project consortium has developed a detailed research agenda for the next 3 years in order to meet the objectives defined in the project. As the project only started a few weeks ago and is currently involved with the details of the system design, there are of course no detailed technological results to be reported so far.

### **3 Partners**

The LISTEN consortium is composed of 5 experienced partners, which complement each other perfectly in order to achieve the objectives of the project. Three important research institutes (GMD<sup>2</sup>, IRCAM<sup>3</sup>, IEMW<sup>4</sup>) bring their scientific and technological expertise and resources to the consortium. The partner representing the end users and content authors (Kunstmuseum Bonn<sup>5</sup>) is from the artistic/cultural domain and will guarantee for a high quality of the public prototypes. The industrial partner (AKG<sup>6</sup>) is a world-leader audio technology company who will ensure that the project results correspond to real-world needs and meet industrial-strength standards of quality and usability. The consortium is completed by a group of artists, composers and independent consultants (the most prominent of which is Larry Sider, director of the School of Sound<sup>7</sup>) who helped to shape the project and will continue to actively support it through its lifetime.

### **4 Artistic Dimension**

The LISTEN project was born out of an artistic vision of a new type of sound work, a kind of dynamic soundscape evolving through the behavior of the audience. The desire to inscribe such virtual soundscapes into real architecture and thus artistically articulate virtual auditory space and real visual space was the driving force for the development of the project over the last four years. Applications for immersive audio-augmented environments outside the strictly artistic domain had to be identified to gain the necessary scientific and industrial momentum for a project of such volume to happen. The social and economic relevance of the new technology had to be inquired and argued to convince the European Commission to support the project. Although many new and exciting perspectives on the project were gained during its extended preparation period, the original motivation of the LISTEN project - to create a new form of multi-sensory experience - remained its central concern. We hope that the project will stimulate the imagination of many artists and composers. Besides its technological objectives, LISTEN has been designed to be a forum for artists interested in immersive audio-augmented environments. Please feel free and encouraged to get in touch with the project in order to share and challenge our vision.

---

<sup>2</sup> GMD – German National Research Center for Information Technology, URL: <http://www.gmd.de>

<sup>3</sup> IRCAM – Institut de Recherche et Coordination Acoustique/Musique, URL: <http://www.ircam.fr>

<sup>4</sup> IEMW, Vienna University of Technology, URL: <http://www.iemw.tuwien.ac.at>

<sup>5</sup> Museum of Modern Art of the City of Bonn, URL: <http://www.bonn.de/kunstmuseum>

<sup>6</sup> AKG Acoustics GmbH, URL: <http://www.akg-acoustics.com>

<sup>7</sup> School of Sound, URL: <http://www.schoolofsound.co.uk>