Location Models for Augmented Environments

Joachim Goßmann and Marcus Specht

Fraunhofer-IMK and Fraunhofer-FIT

joachim.gossmann@imk.fraunhofer.de, marcus.specht@fit.fraunhofer.de

Introduction

In the following paper we will describe two projects on contextualised computer systems and audio augmented environments we are currently working on at Fraunhofer Institutes FIT and IMK.

During the finished EU project HIPS [1]the prototype hippie was developed at Fraunhofer. Hippie is a nomadic information system that supports mobile information access from multiple platforms. It allows to browse exhibition information in a personalized way. Detailed features of a prototype system and evaluations are described in (Oppermann and Specht 2000).

The second one is the EU project LISTEN[2] (Eckel 2001) (LISTEN 2001) which started in January 2001. LISTEN 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.

Both systems have several models to present individualized media and create augmented environments in common:

- World Models (= Space Model, Location Model) describing space the user moves through and thereby interacts with the system.
- Augmentation Layer on World Model: which describes the areas in the location model that contain active information or sound objects (Zones, Segments, Triggers, Agents) which interact with the user of a system
- Domain Model which describes (with MetaData) the information of sound objects and other hypermedia objects which are connected to the physical space via the augmentation layer
- User Model which holds profile information about the user. While the user moves in physical space events are send to the user model and by these events the model is refined.

In this paper we will only focus on the world models and the augmentation layer. Both projects are based on completely different technologies and will use different representation methods and interaction facilities. While in hippie users are moving with small laptop computers or wearables with a small visual display, in LISTEN users will have only a wireless headphone displaying 3D audio. In the following section we will describe both projects mainly from the perspective which representation approach was chosen for writing location models, and the augmentation layer, and which are the shortcomings and advantages of the different approaches. Furthermore the requirements of the different types of information presentation (hypermedia pages vs. auditory display) in the two projects are quite different. From our point of view the requirements for a more fine grained location sensitivity in LISTEN has an important impact on the selection of the representation approach and also on the selection of tracking technology.

---

[1] The prototype Hippie was developed by GMD within the project Hyperinteraction within Physical spaces (HIPS), an EU-supported LTR project in ESPRIT I[3].

[2] LISTEN – Augmenting everyday environments through interactive soundscapes, Fifth Framework Programme, Creating a user-friendly information society (IST), Contract no.: IST-1999-20646.

Hippie: A mobile exhibition guide

The Space Model

In hippie all objects are described based on an ontology of objects and their relations and roles. In this ontology objects for describing the space model and also object types of the augmentation layer are described. Two examples are given in figure 1:

```
(defClass hipsposition ()
  ())

;;; absolute and relative positions used for describing the room layout
(defClass absolute-position (hipsposition)
   ((latitude :type number)
    (longitude :type number)
    (altitude :type number)))

;;; the relative position is mainly for indoor where no absolute GPS coordinates are available
(defClass relative-position (hipsposition)
  ((xCoord :type number :accessor xCoord :initarg :xCoord :initform nil)
   (yCoord :type number :accessor yCoord :initarg :yCoord :initform nil)
   (zCoord :type number :accessor zCoord :initarg :zCoord :initform nil)
   (releated-absolute-position :type absolute-position)))

;;; areas are polygons described by a list of positions
(defClass hipsarea ()
   ((position-list :type list)))

(defClass physical-container (container)
  (:hipsarea :type hipsarea))

(defClass room (physical-container)
  ())

;;; describing artworks and their content
(defClass artwork (unit)
  ((related-objects :type list :accessor related-objects)
   (container :type container :accessor container :initarg :container :initform nil)
   (home :type string :accessor home :initarg :home :initform nil)
   (artist :type artist :accessor artist :initarg :artist :initform nil)
   (title :type string :accessor title :initarg :title :initform nil)
   (dateline :type list :accessor dateline :initarg :dateline :initform nil)
   (occasion :type string :accessor occasion :initarg :occasion :initform nil)
   (history-of-object :type history-of-object :accessor history-of-object)
   (epoche :type epoche :accessor epoche :initarg :epoche :initform nil)
   (style :type style :accessor style :initarg :style :initform nil)
   (motive :type motive :accessor motive :initarg :motive :initform nil)
   (additional_sources :type list :accessor additional_sources)))
```

Figure 1: Basic ontology classes to describe the hips space model and the contained art objects

The basic entities for positions allow for description of areas and points and build up a very simple model of connected entities in a physical space layout like a floor plan of connected rooms and the connections (doors, steps, elevators). In this floor plan the information objects also have a position in most cases described as a point.

The augmentation layer

In hippie Infrared emitters of different granularity and an electronic compass were used to track the user's current position and direction and to relate them to objects in the physical world.

The IR system mainly consists of:

- The IR emitters placed in physical space: Different types of IR emitters are available depending on the objects they were attached to. The IR emitters where configurable for range and angle and could vary between 1 and 10 m range. Nevertheless they could only be adapted by hand and we did not have an exact measure for the current range to model the IR cone precisely with space model coordinates.
- The electronic compass was integrated with IR receiver badges attached to the client machine of the user and could detect the current direction of the user.
- The IR& Compass scanner software: the software was running on a client machine of the user and detected IR signals in the current environment of the user. The software could detect several signals in

parallel and filter the strongest signal of the incoming IR identities. Furthermore it integrated IR signals and compass information in one protocol and sent the location information to the server. The IR and compass software is configurable in several ways: A threshold for filtering IR signals, the threshold for triggering the sent message about the user's location.

In hippie a curator or administrator of the system can load different exhibition objects on top of a space model and describe the art objects placed in the space model. After loading the exhibition objects and the contained artworks the curator can load different set-ups for the infrared locators to describe the positions of infrared emitters in the space model layout. The representation of the augmentation layer mainly was influenced by the type of tracking that was possible with the IR emitters where users can be detected inside an IR cone but no continuous tracking is possible.

```
;;; the painting Geigender Orpheus placed in a room containing the relative hipsposition
(setf (gethash "IV-1" *entity-table*)
      (make-instance 'painting
        :name "Geigender Orpheus"
        :hipsposition (make-instance 'relative-position
                        :xcoord 27.6
                        :ycoord 13.2
                        :zcoord 3)
        :abstract "... "
        :artist "Das Bild stammt entweder aus der Sammlung Centurione in Genua oder es handelt
                 sich um ein Werk von Nicole Regnier."
        :dateline "Das Gemälde ist im 16. oder 17. Jh. entstanden."
        :epoche nil            :style "Barock"
        :motive '("Orpheus")    :size '("Hochformat")
        :material "Öl auf Leinwand"
        :genre "mythologie"))

;;; an Irlocator placed close to the artwork Geigender Orpheus
(setf (gethash 68 *IrLocator-table*)
      (make-instance 'IrLoc
        :id 68
        :hipsposition (make-instance 'relative-position
                        :xCoord 27.5 :yCoord 15 :zCoord 0)
        :object-list '("IV-1" "I-4" "Marcus Specht")))
```

Figure 2: A painting and an IR locator connected to it in the exhibition database for Castle Birlinghoven

Basically the positions of the infrared locators are just hips-positions and not hips-areas, because the IR emitters could just be adapted by hand for the range of the emitted IR cone. This does not allow for high flexibility in setting up new IR-locator configurations and fine grain position tracking of users.

Another major shortcoming was that the positions of the IR emitters, the art objects, and all the areas of the rooms in the space model must be known or measured. As an alternative approach the system can work with IR identities and use no position information at all. Like shown in figure 2 IR-locators could be directly connected to objects which allows the system to connect a received ID even with a moving object like another visitor who has an IR emitter attached (see object-list in IR-locator 68, which is connected to the entity "Marcus Specht").

The LISTEN World Model

The LISTEN World Model is a detailed VR-based geometric model. The model is created for the AVANGO application (Tramberend 1999) and is described as a geometric scene graph. Therefore, a LISTEN environment can be tested and protoyped in a CAVE system (Eckel 2001), or be explored in real space with virtual audio content displayed through a wireless motion-tracked headphone.

In a LISTEN environment, the space the user moves through is addressed in three interdependent, but not necessarily coherent layers:

- The space model, containing geometric information about the real exhibition space and the objects within it, that is needed to allow exploration of the space in a CAVE system.
- The location model, filtering the position and motion of the user by dividing the dimensions the user moves through (location and orientation) into meaningful constraints and deriving continuous parameters from them.
- The virtual acoustic space, in which the location of virtual sound sources and spaces are defined.

The LISTEN location model

In a LISTEN environment, content is displayed to the user in form of a spatially rendered, continuous multi-layered audio stream. Next to the automatic adaption of sound scene rendering to the position and orientation of the user's head, the audio stream is controlled in two ways: Events (mediated interaction), that are used to start and stop the playback of information items in form of audio recordings, and continuous control (immediate interaction) changing parameters in the audio-generation of the presentation (e.g. a sound that gets continuously louder as you approach a certain position within the space).

The location model needs to provide the data-sources from which this interaction can be created,

- to create an acoustic spatio-temporal dramaturgy based on the spatio-temporal behaviour of the user
- to guide the user and provide a detailed acoustic feedback about her or his interaction with the system
- to be able to escort the encounters a user has with the real and virtual objects of a listen set and environment with a detail corresponding to that of a natural sound environment
- to provide all tools necessary to create virtual sound sculptures, parametric collages and other artistic applications

We therefore created structures dividing the dimensions a user's head moves through (location and orientation) into meaningful Segments and Zones:

- A Zone is a region, e.g. a cube, in space. It is "on" when the user's head is inside the region and "off" when the head is outside. It can be an arbitrary 3D body model that provides the necessary functionality.
- A Segment can be imagined as a portion of a 360º panorama. If a measured angle is within the portion, it is "on", "off" when outside. A Segment can both be imagined with the user as point of reference or target.

To achieve immediate interaction, it is necessary to derive continuous parameters from the motion of the user in space by immersing the user into parametric fields. This is done by attaching an Evaluator to a Zone or Segment. Evaluators provide a spatial envelope function, thereby allowing Zones and Segments to have a detailed continuous parametric "profile". These parameters are later on scaled to be used for any part of the sound and presentation generation. Two examples for a segment with a panoramic evaluator and a 2-d Zone with a centroid evaluator are shown in figure 3 and figure 4.

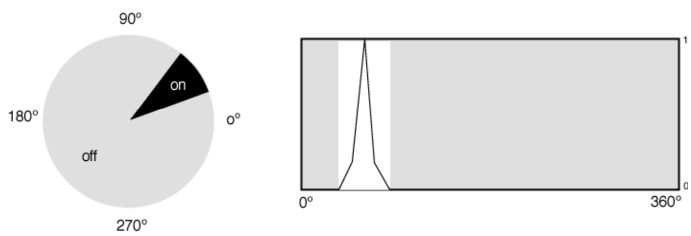

Figure 4: Segment and a panoramic evaluator

A more complex Evaluator could provide a value-profile that is constrained by a Zone. The concept of the Evaluator is very expandable: A landscape that changes its values with the temporal behaviour of the user (e.g. setting places where the user has been to 0) could be imagined within the range of the concept.

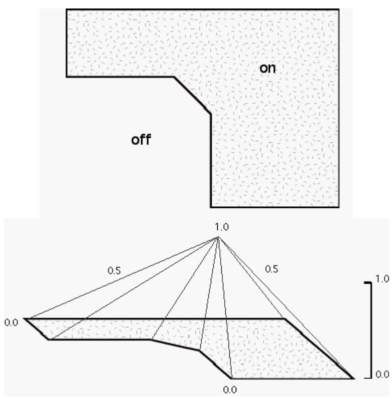

Figure 4: 2d-Zone and 2d-Zone with a centroid evaluator

These elements can be combined into activity graphs creating a hierarchical location model: The children of a Zone are only checked and evaluated if their parent is active („on"). The zones and segments are represented internally as a graph of nested activateable objects, an example graph can be seen in figure 6.

Relating to exhibition objects (Proxies)

Proxies provide us with information about their position and size relative to the user's position:

1. The angular boundaries of the object in respect to the user position, therefore the relative size of the object for the user's perspective (aspect dimension).
2. Angle between the user's nose and the vector to the centre of the object (user angle).
3. Angle between the main direction of the object and the vector to the user position (object angle)
4. Distance between the user and the centre of the object (object distance)

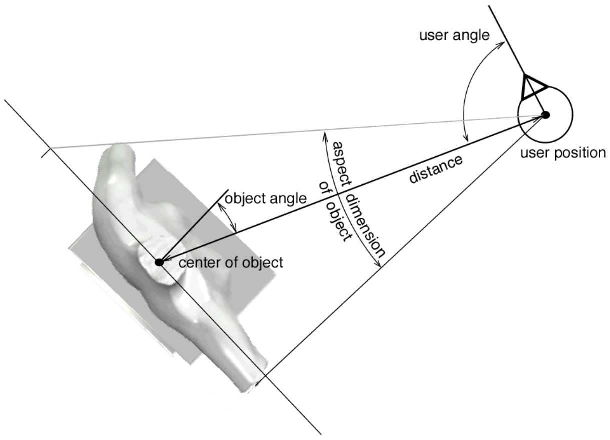

Figure 5: The geometric relationship between visitor and object.

This information, derived from the geometric space model, is used to control the size and properties of Zones and Segment in the location model:

Example: multiple aspects

As an example we assume that the statue has three different interesting perspectives that each require a comment only audible at the respective position. Each position can be defined by object angle and distance, and is of course only valid if the visitor is facing the statue (if the user angle is within the aspect). The Evaluators in the following dependency graph can be used to guide the visitor to the desired position in space:

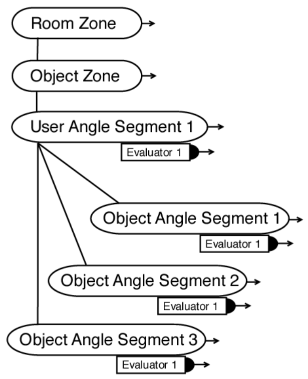

Figure 6: Example Activity Graph

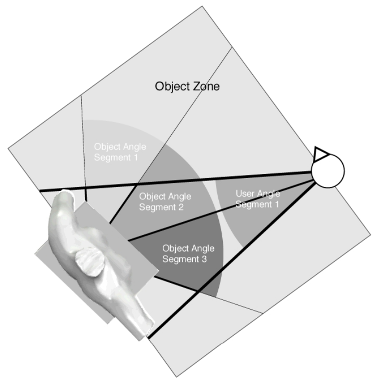

Figure 7: Example Location Model Illustration

The LISTEN tracking system

In contrast to the HIPS project, there are very high demands on the tracking technology that arise from the necessity to immerse the user into a convincing virtual acoustic scene (Bregman 1990): Continuous low-latency tracking of the position of the user's head and its orientation covering the entire area to be augmented is necessary. Tests concerned with acoustic VR have shown that the total system latency (from the head motion to the reaction in the sound presented through the headphone) must be below 59 ms (Wenzel 1998), and the spatial resolution has to be in the centimeter range. A tracking system of the mentioned resolution will easily allow us to detect the spatial structures we propose. The electromagnetic tracking module for LISTEN is currently developed at IEMW, Vienna University of Technology, URL: http://www.iemw.tuwien.ac.at. (Goiser 1998).

Comparison of approaches

Both projects aim at producing augmented environments for museum-based applications. Nevertheless each of the presentation media targeted has specific requirements for the granularity of the tracking system, the space modelling and the augmentation layer. Hips is dealing with visually displayed factual information items such as texts and images, while the information display in LISTEN is entirely time-based and tries to explore the potential of the acoustic medium to the fullest. In hips, hypermedia pages need to be updated as the user is accessing information about an art object, but in LISTEN, constant updating is necessary to adapt the sound scene continuously in a way that is comparable to a natural sound environment. The information content of spoken word is only to a rather small aspect of acoustic information (Bregman 1990), The creation of a LISTEN presentation requires a large amount of additional scripting to interpret and use the events and parameters produced by the location model, controlling the flow of the presentation.

Conclusion and future work

Some of the restrictions of hippie will be overcome by the approach of LISTEN. Using the CAVE system to simulate augmented environments will allow for new ways to evaluate ubiquitous computing systems and modelling approaches. Next to the described location model, a detailed analysis of the user motion is also under investigation. The highly detailed augmentation layer of listen will be evaluated in terms of authoring practicability. Actual test scenarios include two virtual LISTEN prototypes that are created until summer 2002, and a physical prototype that will be installed in the Kunstmuseum Bonn, Germany in January 2002. From our point of view, the success of the auditory medium evolving in LISTEN relies strongly on the user navigation technique. With it, we hope to trigger new notions in using virtual acoustical spaces within physical visual environments.

References

Bregman, A. S. (1990). Auditory Scene Analysis: The Perceptual Organization of sound. Cambridge, Massachusetts, MIT Press.

Eckel, G. (2001). Immersive Audio-Augmented Environments. 8th Biennial Symposium on Arts and Technology at Connecticut College, New London, USA, CT.

Eckel, G., Beckhaus, S. (2001). ExViz: A Virtual Exhibition Design Environment. International Symposium on Virtual and Augmented Architecture (VAA'01),, Dublin, Ireland, Springer Verlag Wien, New York.

Goiser, A. M. J. (1998). Handbuch der Spread-Spectrum Technik, Springer-Verlag Wien New York**:** 152-158.

LISTEN (2001). The LISTEN Website.

Oppermann, R. and M. Specht (2000). A Context-Sensitive Nomadic Exhibition Guide. HUC2K, Second Symposium on Handheld and Ubiquituous Computing, Bristol, UK, Springer.

Tramberend, H. (1999). Avango: A Distributed Virtual Reality Framework. IEEE Virtual Reality '99 Conference, Houston,Texas, USA.

Wenzel, E. (1998). The impact of system latency on dynamic performance in virtual acoustic environments,. 5th International Congress on Acoustics and 135th Meeting of the Acoustical Society of America, Seattle, WA.