

# Interacting with Projected Displays by Means of a 3D Interface and an Instrumented Bracelet

Lübmira Spassova\*  
Saarland University  
Germany

## ABSTRACT

This paper introduces a 3D user interface and a concept for an interaction device that we refer to as an *instrumented bracelet*. Both interfaces are purpose-designed to facilitate user interaction with the AR projection system *Fluid Beam* [7]. The 3D interface is a desktop application that enables the creation and manipulation of projected displays (*virtual displays*) in the environment. With the instrumented bracelet, the user will be able to interact more freely and more intuitively with the projected displays using arm movements and speech.

**Keywords:** Ubiquitous computing, 3D interface, steerable projector, projected displays, wearable interaction device.

## 1 INTRODUCTION

In the area of ubiquitous computing, technology tends to disappear in the environment and become a part of everyday objects. This trend also affects the user input and output interfaces. By means of projection, an ordinary room can be turned into a continuous output interface in which each suitable surface can be used to display visual information. In this way, the whole environment can be turned into an output interface. But not only visual output can be displayed in 3D. By means of a spatial audio system (see section 5.2) virtual sound sources can be created and positioned at desired locations in the environment. Thus acoustic output can also be used as a three-dimensional feature.

In order to enable an easy handling of these new functionalities, we have to build appropriate interfaces that cope with the three-dimensional aspects of the applications.

## 2 RELATED WORK

### 2.1 Steerable Projection

So far, several projects have dealt with environment augmentation using projection. Probably the most popular one is the *Everywhere Displays Project* [4] developed at the IBM Research lab. It uses a device consisting of a fixed-mounted projector and a pan/tilt mirror in front of its lens, with which the projector beam can be reflected in different directions. A pan/tilt camera mounted near the projector can observe the user's hand and recognize interactions like button clicks.

A steerable video projector capable of displaying images at different flat surfaces in its vicinity is described in [1]. The system uses homographies in order to correct the image distortion. A camera attached to the projector allows the recognition and tracking of so called portable display screens in real time. These are simple cardboard surfaces with dark boundaries on which rectified images can be projected even when they are being moved.

\*e-mail:mira@cs.uni-sb.de

### 2.2 Wearable Interaction Devices

In the area of wearable computing, the development of suitable interaction devices is essential. In [5], Rekimoto describes a pair of devices called *GestureWrist* and *GesturePad*, which are used to recognize gestures and arm movements for interaction with wearable or nearby computers. Two different gestures (making a fist and pointing) are recognized by measuring the change in the shape of the wrist by means of several capacitive sensors in the wrist band. The position of the forearm is detected with an acceleration sensor. The *GesturePad* consists of an array of capacitive sensors that can detect the proximity of a finger tip. The author proposes the integration of the input devices into clothes.

*SCIPPIO* [10] is a miniaturized building block for wearable interaction devices. It consists of an MCU, to which several sensors can be attached, a bluetooth interface for wireless data transfer and a battery. Additionally, an LED and a small speaker are integrated to generate simple visual and audio feedback. For evaluation purposes, the *SCIPPIO* building block was used to create a data glove. A dual axis tilt-sensor to detect hand-rotation activities was integrated as well as three micro buttons attached to fingers in the glove to enable the triggering of arbitrary actions. Moreover, RFID marker detection is supplied by an RFID scanner in the palm of the glove.

## 3 THE FLUID BEAM SYSTEM

*Fluid Beam* [7] is a system for distortion-free projection on suitable surfaces using a steerable projector and camera unit (see figure 1). The steerable device is mounted at the center of the ceiling of the instrumented room and contains a 3.300 ANSI lumen LCD projector and an off-the-shelf digital camera with 4 megapixels and a low resolution video stream. It can be rotated around two axes (pan and tilt) and can thus be directed at nearly any point in the room. However, when projecting on a surface from an oblique angle - which is the usual case in our setup - the displayed image appears distorted. In order to avoid this distortion, *Fluid Beam* software was developed to pre-warp the image that is to be displayed using an approach described in [4].



Figure 1: Steerable projector and camera unit (*Fluid Beam*)

In this way, we obtain a so called *virtual layer* covering the environment, on which *virtual displays* can be placed at fixed positions or moved along the surfaces in the room. The content of a virtual display can be a simple image, a movie or a live video stream. Virtual displays are visible only when they lie within the outlines of the projector beam, which means that the steerable projector serves

as a *virtual torch* and makes the virtual displays visible when it is directed at them. This technique makes it possible to store visual information spatially in the environment and to make it accessible when needed. A virtual display can be placed for example next to a complex device (e.g. a printer), so that it can show its operating instructions. As soon as the system recognizes that a user might want to work with the device, the steerable projector is directed at the virtual display and the instructions are made visible.

Virtual displays are also used to display visual highlights (spots). In *SearchLight* [2], such visual highlights are used for the purpose of searching for objects located in the environment. This is done by using the camera of the *Fluid Beam* device to scan the environment for optical markers (ARToolKit<sup>1</sup>). If any markers are detected, the system computes their 3D positions in the room and stores them together with the corresponding marker IDs. The user can then ask for the position of some marked object and the system draws the user's attention to the searched item by projecting a highlight on it. This system can be applied in shopping malls or in big warehouses to help the users find the products they are searching for.

A more complex application using the *Fluid Beam* system is the *Virtual Room Inhabitant (VRI)* [3], an avatar "living" in the instrumented environment and having the role of an assistant for unexperienced users. The implementation of the *VRI* combines three main parts: the *Fluid Beam* system, handling the visual output of the avatar, a spatial audio system (see section 5.2) responsible for the acoustic output, and the *Character Engine*, which defines the behavior of the avatar and controls the steerable unit and the spatial audio system.



Figure 2: Virtual Room Inhabitant (Cyberella) beside a plasma screen

The visual appearance of the female avatar Cyberella (see figure 2) is implemented as a sequence of Macromedia Flash MX<sup>2</sup> movies that can be seamlessly plugged together. Each movie shows a different character motion or gesture. In this way, the avatar gestures can be combined arbitrarily in a desired order. Each animation also includes an optional lip movement loop, so that the avatar is capable of talking in any given position.

The avatar movie is assigned to a virtual display as a live video stream and can thus be arbitrarily placed and moved on the surfaces of the room. Thanks to the spatial audio system, we can make the voice of the character seem to originate from the position where its visual representation is currently situated. In this way, using graphics and audio, the avatar can "hover" along the walls of the instrumented room and talk to the user from its current position. In our first demo scenario the avatar guides a user through the instrumented environment and explains the functionalities of the different devices.

#### 4 3D INTERFACE

In order to facilitate the creation and placement of virtual displays, we needed an interface that is intuitive and easy to use. The solution was to create a visual 3D model of the physical environment with

which the user can interact (see figure 3). The model was built using Java3D and is displayed in a JFrame programming construct.

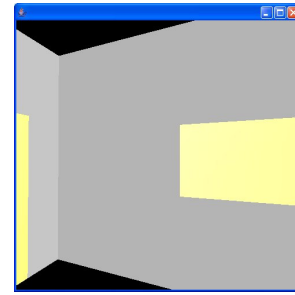


Figure 3: 3D interface with display surfaces (grey) and obstacles (yellow)

Beside the surfaces that are suitable for projection (like walls, desk surfaces etc.), the model also contains obstacles (like doors, windows etc.) on which no projection is possible. In this way, we could implement an algorithm that computes trajectories for the movement of virtual displays avoiding collision with obstacles. Using this approach, we can for example make the *Virtual Room Inhabitant* move through the environment following the user in real time.

In our model, projection surfaces are represented in grey and obstacles are rendered in yellow so that they can be easily distinguished. The 3D model can be rotated horizontally and vertically by clicking on it with the left mouse button and dragging. Clicking and dragging with the right mouse button on a projection surface opens a rectangular frame representing the outlines of a virtual display to be created. By releasing the right mouse button, the user creates a virtual display with the given shape, which is projected at the corresponding position in the physical environment. At the same time, a representation of the virtual display is created in the 3D model (see figure 4).

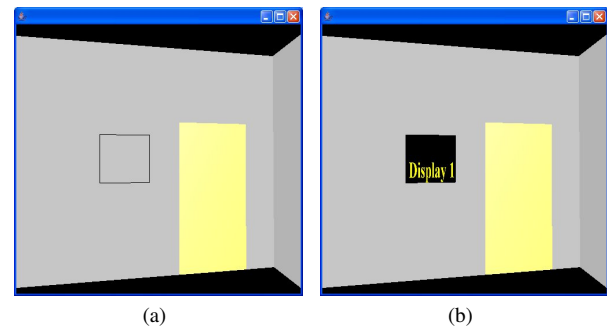


Figure 4: Display creation: (a) frame representation during mouse drag, (b) final representation with display ID

At this stage, the display still has no content so by default it shows its own ID. The user can now define the display content by drag-and-dropping images or videos from the desktop on the representation of the display in the 3D model of the interface. Thus, the chosen image appears both on the projected virtual display and on the corresponding representation in the model. When a video is shown on the projected display, the representing display in the interface then shows only a movie symbol (see figure 5). The visual content of a virtual display can be re-defined at any time. By dropping a new image or video file on the display representation, the old content is replaced.

<sup>1</sup><http://www.hitl.washington.edu/artoolkit/>

<sup>2</sup><http://www.macromedia.com/software/flash/>

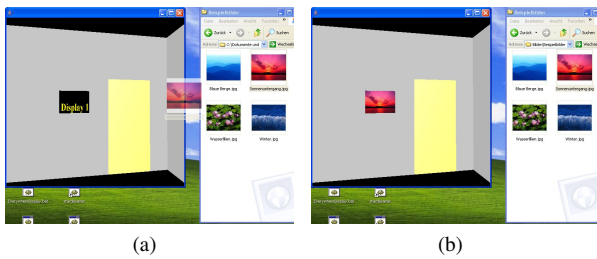


Figure 5: Defining display content using drag and drop: (a) image file being dragged, (b) image set as display content

After the virtual display is created, it can be moved to a new position by clicking and dragging with the left mouse button on the corresponding representation in the interface. The virtual display projected in the room and the corresponding display in the 3D model then move in parallel and change their orientations according to the orientation of the surface they are currently placed on, i.e. in particular, the displays flip around their Y-axes when they move around a corner from one wall to another.

Additionally, the user has the opportunity to change the size and the position of a virtual display in a menu that appears after a left click on the corresponding representation in the interface (see figure 6). This allows a more exact adjustment of the parameters than with the mouse interaction.

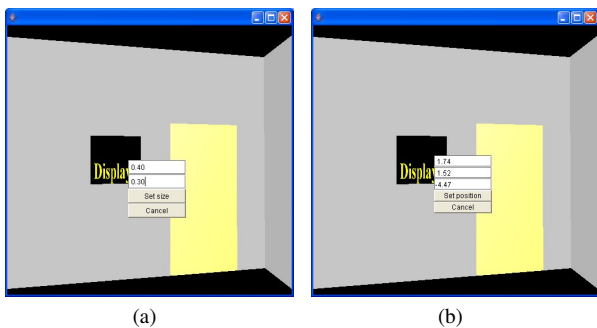


Figure 6: Menus for (a) size and (b) position adjustment

## 5 INSTRUMENTED BRACELET

The 3D interface described in the previous section is a desktop application. This means that although the user works in 3D, he or she is still bound to the PC screen. A more intuitive approach would be to let the user interact with the steerable projector and camera unit and with the virtual displays directly in the physical environment.

### 5.1 Concept

For this purpose, we developed the concept of an instrumented bracelet with which the user can manipulate the virtual displays and change the orientation of the steerable unit by performing simple arm movements. The bracelet, which is to be worn tightly around the right wrist, will recognize the position of the palm and detect arm movements in the direction in which the palm is facing. Movements in any other direction will be ignored. This allows the user to perform "wiping gestures" in different directions as an abstraction of pushing things in a certain direction. The user must also be able to determine the target of the interaction, i.e. the object that is to be moved. Interaction targets can in this case be the different virtual displays or the steerable unit itself. In this way, the user will be able to "push" a certain virtual display to a new position or direct

the projector beam (i.e. the virtual torch) towards a certain display to make it visible.

### 5.2 Implementation

In order to determine the orientation of the palm, the bracelet can be fitted with a tilt sensor, and the arm movements can be detected using an acceleration sensor. Additionally, the bracelet can be fitted with a microphone with which it can be switched on and off (e.g. by finger clicks) in order to avoid unintended interaction while performing other tasks in the room. All sensors should be connected to a wireless module (e.g. bluetooth) which transmits the detected signals to the stationary PC.

In addition to on and off switching, the microphone can also be used to issue a voice command to the system. In this way, the user can combine different modalities - audio and body gesture input - to interact with the projected displays and the steerable unit, which will extend the abilities of the system.

Another interesting opportunity where the microphone on the bracelet can be applied is the generation of voice triggered messages. The user can record a message and then perform a triggering event (e.g. laying his or her hand on a certain place) to "leave" it at a particular location. "Leaving" means in this case that the audio file is associated with a 3D position in the room, so that it is played as soon as the steerable unit is directed at it. This means that the user can deal with audio files the same way he or she does with images and videos. In this way, we achieve consistency between visual and acoustic information.

For a more authentic user experience, it is possible to make the sound of the stored message appear to come from the position at which it was left. The audio system SAFIR [6] installed in our instrumented environment enables the creation of spatial sound at any position in the room. Given a sound file and the desired 3D coordinates, the audio signal is distributed in a specific way between eight loudspeakers installed below the ceiling of the room, thus simulating a virtual sound source with the specified position. By integrating the SAFIR functionalities in our message leaving application, the user will have the impression that the acoustic information is spatially stored in the environment.

## 6 POSSIBLE SCENARIOS

One can imagine different scenarios where the 3D interface and the instrumented bracelet can be used together with the *Fluid Beam* system, like a museum, an office or a supermarket.

In a museum environment for example, virtual displays can be placed beside the different exhibits, so that information about the respective exhibit can be shown on them. In this case, the 3D interface can be used by the system administrator to define the positions and the content of the different displays. The museum guide can then wear an instrumented bracelet and use it to direct the steerable projector and camera unit towards the different virtual displays on the tour thus making information visible to the audience. The advantage of using projected displays in this case is that they can be easily placed almost anywhere and one does not have the effort of buying and installing several stationary screens. Many museums are also against permitting such modifications of the infrastructure. If required, the content of the virtual displays can be easily modified using the 3D interface and the positions can be re-adjusted if the museum setup is changed.

Users in an office scenario can apply the instrumented bracelet in order to place as well as to visualize different types of information on virtual displays in the environment. In the same way, the bracelet can also be used to leave and receive voice messages (as described in section 5.2). User who work in the office can create their own virtual office mail boxes, i.e. personal virtual displays that others can use to leave them messages. For privacy reasons, it must be guaranteed that only the owner of a personal virtual display can

access its content. This can be done by integrating an ID in each instrumented bracelet, so that only authorized persons are allowed to access personal information.

Virtual displays can also be used to show product information or for advertising purposes in supermarkets. There is already an application called *Product Associated Displays (PADs)* [8] that uses the *Fluid Beam* system in a retail scenario. It uses an instrumented shelf [9] which has the ability to recognize the presence or absence of products fitted with RFID tags. In this way, the system detects when a product is taken out of the shelf and it creates a *Product Associated Display* at the former location of the product at the back-plane of the shelf. The created *PAD* is a virtual display showing an image of the associated product. Now the user can ask for information about this product using his or her PDA. The answer to the user's request is then displayed on the corresponding *PAD*. In the same way, commercials or references to related products can also be displayed on a *PAD*. Again, the 3D interface can be used to define the positions of the virtual *PADs*, and the instrumented bracelet can be applied to make the information visible.

The *Virtual Room Inhabitant* can be used in different ways in each of the above mentioned scenarios. In a museum, it can play the role of a tour guide and lead or accompany the visitors on their way. The visitors or a human guide can be provided with instrumented bracelets so that they can direct the avatar explicitly to exhibits they are interested in.

The application of the *VRI* as an assistant in an office scenario was already described in section 3. Here, the 3D interface can be used to predefine the particular locations and the movement of the virtual display on which the avatar is shown, as well as the different gestures and speech acts of the avatar at each location.

In a retail scenario, the *VRI* can either appear as an assistant when the user asks for information or help about a product, or guide the user to an area or a product he or she is searching for. The 3D interface and the instrumented bracelet can be applied as described above in this section.

## 7 CONCLUSION AND FUTURE WORK

In this paper, we introduced two interaction techniques for the augmented reality system *Fluid Beam*. The first one is a 3D interface for creation and manipulation of projected displays implemented as a desktop application. The second one is an instrumented bracelet that is conceptually designed to enable intuitive interaction with projected displays in the physical environment by means of arm movements and speech. After a description of the concept, we discussed our considerations about different implementation aspects for the proposed device and described several scenarios in which the two interaction techniques can be applied.

As the instrumented bracelet is work in progress, we plan to realize the concept in an actual implementation and analyze the functionalities and their applicability in a test scenario.

## REFERENCES

- [1] S. Borkowski, O. Riff, and J. L. Crowley. Projecting Rectified Images in an Augmented Environment. *ProCams Workshop, IEEE Computer Society Press*, 2003.
- [2] A. Butz, M. Schneider, and L. Spassova. SearchLight: A Lightweight Search Function for Pervasive Environments. *International Conference on Pervasive Computing*, 2004.
- [3] M. Kruppa, L. Spassova, and M. Schmitz. The Virtual Room Inhabitant - Intuitive Interaction With Intelligent Environments. *18th Australian Joint Conference on Artificial Intelligence*, 2005.
- [4] C. Pinhanez. The Everywhere Displays Projector: A Device to Create Ubiquitous Graphical Interfaces. *Lecture Notes in Computer Science*, 2001.
- [5] J. Rekimoto. GestureWrist and GesturePad: Unobtrusive Wearable Interaction Devices. *International Symposium on Wearable Computers*, 2001.

- [6] M. Schmitz and A. Butz. SAFIR: Low-Cost Spatial Audio for Instrumented Environments. *2nd International Conference on Intelligent Environments*, pages 427–430, 2006.
- [7] L. Spassova. Fluid Beam - A Steerable Projector and Camera Unit. *Doctoral Colloquium at ISWC/SMAR*, 2004.
- [8] L. Spassova, R. Wasinger, J. Baus, and A. Krüger. Product Associated Displays in a Shopping Scenario. *4th IEEE/ACM International Symposium on Mixed and Augmented Reality*, pages 210–211, 2005.
- [9] R. Wasinger, A. Krüger, and O. Jacobs. Integrating Intra and Extra Gestures into a Mobile and Multimodal Shopping Assistant. *3rd International Conference on Pervasive Computing*, pages 297–314, 2005.
- [10] H. Witt, R. Leibrandt, A. Kemnade, and H. Kenn. SCIPIO: A Miniaturized Building Block for Wearable Interaction Devices. *IFAWC - 3rd International Forum on Applied Wearable Computing*, 2006.