Simulating and Evaluating Public Situated Displays in Virtual Environment Models

Christoph Stahl
Saarland University
P.O. Box 15 11 50
D-66041 Saarbrücken, Germany
+49 681 302 3191
stahl@cs.uni-sb.de

Jens Haupert
Saarland University
P.O. Box 15 11 50
D-66041 Saarbrücken, Germany
+49 681 302 64047
haupert@xantippe.cs.uni-sb.de

ABSTRACT
In this position paper, we address the problems that arise during the design phase of intelligent environments that make use of public situated displays for user assistance. We propose a new design process, which is based on an architectural model of the environment. It employs a toolkit that allows the designer of an intelligent environment to verify the visibility of displays from various virtual viewpoints before they are actually acquired and deployed. Our approach furthermore allows the early evaluation of application prototypes. We mirror the screens of real machines to the virtual displays and use an avatar as a positioning loopback device in order to test the behavior of context-aware presentations.

Categories and Subject Descriptions
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Theory and Methods, User-centered design, Interaction Styles*

D.2.1 [**Software Engineering**]: Requirements/Specifications – *Methodologies*

General Terms
Design, Human Factors

Keywords
Models, Principles, Intelligent Environments, Ubiquitous Computing

1. MOTIVATION
Public situated displays have great potential for user assistance in intelligent environments, and several applications have been published in [1]. They can be used to complement personal mobile devices such as mobile phones and PDAs. These small devices are always available to the user, but their display resources are strictly limited due to the constraints of their form factor. Whereas public displays offer large screen spaces, their visibility is restricted to certain locations. However, this restriction can be beneficial for presentations that are designed for a specific spatial context.

Traditional signage applies their limited visibility to convey context-related information, such as sales offers, opening times, room occupancy, but also local rules and prohibitions. A sign that reads “no smoking” for example is not intended to have a global effect, but only to stop people from smoking inside the room where they can read it. In addition, signs have a fixed orientation with respect to their surrounding environment, so that they are especially useful to assist us in our wayfinding tasks.

Electronic displays, even when they are non-interactive, offer more flexibility and can adapt their content to the situation. In intelligent environments, they can even sense the users and adapt their presentations according to the users’ profiles and cognitive resources. For example, an arrow might dynamically switch its direction according to the goals of each individual user.

However, the design of signs and displays poses difficulties since the designer has to consider the visibility of the displays from various viewpoints, and the interpretation of directions heavily depends on their viewing angle. We all might have experienced traffic situations, where it is unclear whether the sign tells us to turn left or to go ahead. Personalized information is yet more difficult to design, since the presentations are automatically generated and have to be evaluated for a variety of events and situations, such as different user profiles and goals.

Furthermore, testing and evaluating electronic displays comes with high cost for the actual hardware and their installation. It is also clearly unfeasible to try out different positions for a large wall-mounted display, since it is an undesirable and irreversible process to drill holes into concrete and steel.

Hence we propose a new design process, which is based on a virtual model of the environment and employs a toolkit that allows the designer of an intelligent environment to simulate and evaluate public displays from various viewpoints before they are acquired and deployed.

2. THE DESIGN PROCESS

In this position paper, we propose a new approach for the design of user assistance in intelligent environments that is centred on 3D models of the environment. These models represent the architectural features of a place. We make the assumption here that the environment, which is going to be instrumented with an information system for its visitors or inhabitants, already exists (or is at least at the end of the planning phase) and architectural drawings are available to create such a model.

By using our method, the interaction designer will be aware of the spatial context during the whole design process, from the first scenarios to the evaluation of a prototype in a virtual environment. The environment model helps the designer to decide which kind of assistance is required by the user in certain places, and to choose the appropriate interaction devices, such as displays and sensors, based on their visibility and range.

To support this, we have extended the *YAMAMOTO* map modelling toolkit with a new feature that allows the designer to model displays, and we have implemented an egocentric perspective, so that the designer can virtually explore the instrumented environment in order to validate the placement and content of the displays.

The proposed approach is especially beneficial for the design of user assistance applications that include a wayfinding component, which provides navigational aid to the user on public displays. Our method comprises the following steps:

- Modelling architectural features (walls, doors, stairs) and furniture
- Virtually instrumenting the environment and visualizing the placement of displays from an ego perspective
- Prototyping the user assistance application
- Evaluating the assistance application prototype within the virtual environment model
- Deploying the system
- Monitoring the display content in 'mixed reality'

In the following sections, we describe each step in more detail, before we close the paper with a summary and outlook.

2.1 Modelling and Browsing the Environment

For the modelling of the architectural features of the environment, we use the *YAMAMOTO* map modelling toolkit, which has been published in [3]. The editor allows one to visually mark-up walls and doors based on architectural ground plans through polygon meshes. In order to keep the modelling process as simple as possible, each floor is represented in two-dimensional space only. However, through the use of layers, multiple floors and interconnections such as staircases can also be represented. Complex environments may consist of multiple buildings and outdoor areas, so that a single scale large model may not be appropriate for the design process. Hence the toolkit allows one to recursively refine buildings and rooms through submodels of a smaller scale.

The resulting model can be shown either in a top-down projection, birds-eye view, or egocentric perspective. The necessary 3D geometry for a realistic rendering of the building is automatically created on the fly from the 2D outlines by extending the z-axis through an extrusion operation. Some additional object attributes such as ceiling height and object type (wall, door, stairs) are considered.

In addition to the plain floor layout, the modelling of furniture arrangements or queuing barriers would be clearly desirable for a realistic simulation of environments. Unfortunately our toolkit does not yet provide the means to do this.

2.2 Virtually Instrumenting the Environment

Once the environment has been modelled, the *YAMAMOTO* editor provides an interactive view, which helps the interaction designer to identify the places where users are likely to require and request information from the environment in order to pursue their activities and goals.

The designer can now begin to add ubiquitous and pervasive computing elements into the model, such as sensor devices or positional beacons. These devices are modelled through geometric primitives (such as points, circles and sections), that represent their position, range and orientation. Additionally, a symbolic name and ID can be specified for hardware devices. In the *RENA* project for example, we have used the toolkit to model infrared beacons and RFID-tags, which we use for our indoor positioning system, which estimates the position of a mobile device based on the signals received.

In order to model displays within the environment, we have enhanced the *YAMAMOTO* editor, so that the designer of an instrumented environment can choose the display size, aspect ratio (4:3 or 16:9, portrait or landscape) and orientation (tabletop or wall mounted). Since the crucial point in the setup of public displays is their visibility from different viewpoints, the egocentric perspective provided by *YAMAMOTO* helps the designer to verify that the displays are visible to the user and allows to interactively adjust their position, if necessary. The screenshot in Figure 1 shows two wall-mounted public displays, which have been placed next to a door in a corridor.

The designer can assign static screenshots as mock-up presentations to the modelled displays, which helps to judge their comprehensibility with respect to the spatial context. The semantics of a sign showing an up-arrow for example is often ambiguous – does it point forward or upward to the next level? Nearby an elevator, the sign would have a different interpretation than at the beginning of a long corridor.

The most interesting feature however is the ability to mirror the content of networked displays to the virtual environment in real time, which will be explained in the following section.

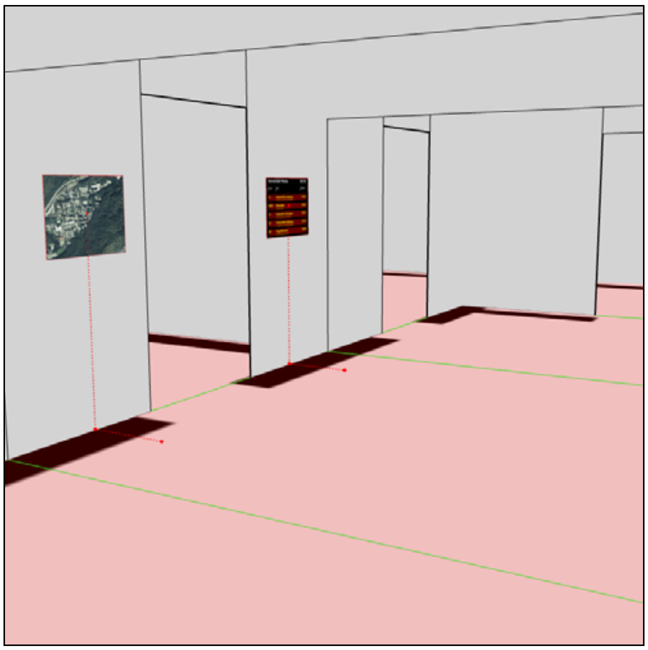

Fig. 1: Modelling public displays with a static mock-up presentation (left) and a VNC real-time capture (right).

2.3 Simulation and Evaluation

In the previous design phases, the designer has created a model of the environment and has virtually instrumented it with ubiquitous computing elements, such as beacons for indoor positioning and public displays. According to the third phase of our proposed design approach, the designer would now develop a first prototype of a user assistance system that provides location-based presentations. However, setting up the indoor positioning infrastructure and public displays in the real environment takes a lot of cost and effort, and is sometimes not even possible at all. In public areas, such as shops or airports, no experimental setup would be tolerated by the management, and the developer has to simulate the whole system somehow before it can actually be installed.

Here the modelling effort of the first two phases begins to pay off, since the developer gets the necessary virtual testing environment for free. Figure 2 shows the evaluation setup, where the real instrumented environment (IE) is shown on the left hand side, and the virtual environment (VR) is depicted on the right. The instrumented environment encloses the user and comprises display devices, distributed computing power for the application logic, and navigational beacons. According to the setup in our RENA project, the user holds a PDA which receives the beacon signals and estimates its position. The position of the user is sent to the application, which sends corresponding presentations to the public displays.

In the virtual environment, the positioning system is simulated through the avatar, which acts as a kind of loopback device. As the designer moves the avatar, location events are sent to the application, to which the whole simulation process is completely transparent. The presentations are rendered on real machines and mirrored to the virtual displays. We have therefore integrated a *VNC* (Virtual Network Computing) [2] client into the *YAMAMOTO* rendering process, which achieves a display update rate of approximately one frame per second, and the virtual environment is rendered with approximately 20 frames per second.

The benefit of this testing arrangement is that both the designer and the system developer can actually see the real outcome of the application logic, which runs in a fully distributed computing environment as is typical for intelligent environments. This approach should ensure that the system will perform well according to the designer's intention once it is deployed in the real environment. Additionally, a first study with real users could be easily conducted in this lab setting.

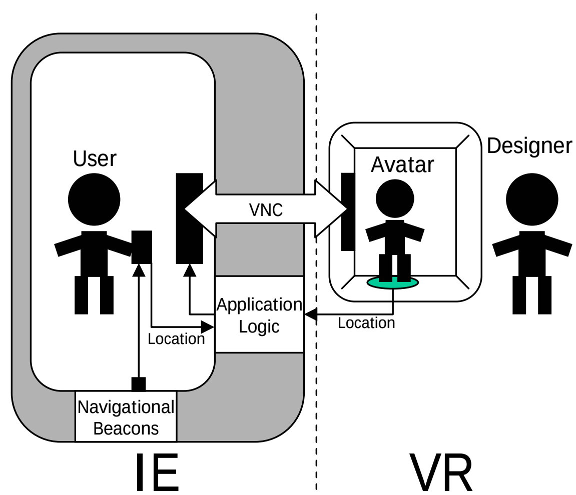

Fig. 2: The VR-Environment provides a positioning loop-back device to evaluate location-aware assistance services.

2.4 Monitoring Real Display Environments

The simulation setting described above can be useful even beyond the evaluation phase. For the administration staff, which is in charge of feeding the installed application with location-based data, such as room occupancy or route knowledge, it might be cumbersome to check the content of the actual displays, which are distributed all around the environment. The virtual environment would provide an intuitive interface for them to monitor and validate the presentations in real time, conveniently from their office. Viewing the display content from an egocentric perspective would help to identify wrong presentations (especially misleading wayfinding directions) much easier than in a simple collection of plain windows without their spatial context.

3. SUMMARY AND OUTLOOK

We have outlined an approach for the design of intelligent environments, which is based on a geometric 3D model of the environment. The model allows the designer to virtually instrument the environment with sensor devices and public displays and can be used to evaluate application prototypes. We mirror the screens of real machines to the virtual displays and use an avatar as a positioning loopback device for location-aware user assistance applications.

The necessary enhancements of the YAMAMOTO toolkit are currently under development, so we could not yet apply the proposed design process to a real-life problem. However, we are planning to do so in the near future. We will also extend the capabilities of the editor so that furniture arrangements can be modeled and the virtual testing environments become more realistic.

4. SHORT AUTHOR BIOGRAPHIES

Jens Haupert is a student of Computer Sciences at Saarland University and has implemented the first version of the *YAMAMOTO* editor in a practical course on software engineering in 2003. Since then he has been working in the Artificial Intelligence Group of Prof. Dr. Wolfgang Wahlster as a research assistant and received his Bachelor degree in October 2005 for his thesis on the hierarchical geo-referenced modeling of environments with the *YAMAMOTO* toolkit. He is currently writing his Master thesis, which includes implementing the features that are described in this paper.

Christoph Stahl has received his diploma in computer science in 2001, and has been working since then as a Ph.D. student in the projects REAL and RENA. There he has implemented several mobile and kiosk-based pedestrian navigation systems and set up the architecture of an instrumented environment. It currently assists its users in their wayfinding and shopping tasks. Currently he is working on a methodology to design and develop user assistance systems that integrate support for multiple activities and make intelligent use of Ubicomp technologies and environments.

5. REFERENCES

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