An Intuitive Interface for Building Management and Planning
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Building management and planning professionals utilize database systems for administrative support, but these systems are inadequate for conveying architectural plans. In this article we describe the so-called Virtual Maquette that was developed at the Eindhoven University of Technology for the board of the University. The Virtual Maquette consists of a vertical display for 3D view and information of building stock, and an interactive horizontal display for manipulation of view and information. Interaction is implemented using infrared tracking of devices that are positioned on the desktop with the projected plan view. Through this interface the states of the buildings can be inspected at different periods in history and in the future. The support of multiple devices in a single environment is a technical challenge, but it provides a new interaction method for non-technical persons.
1. INTRODUCTION

Today, organizations that are responsible for building management, either for their own organization or professionally, apply databases for storage of attribute data about their buildings. These building databases are used for facility management and maintenance, and they are operated by persons with a background in architecture, building or planning [1]. From these data, new plans are produced and cost calculations are made. Since these plans include major costs, final decisions are usually made by the boards of the organizations that own the building property. Given that boards often have limited time and knowledge to properly assess the implications of architectural plans, it is necessary to convey the impact of new plans in an intuitive manner.

The use of interactive models to communicate the effects of architectural plans has been widely acknowledged as successful. It has led to a great variety of systems that support communication between architect or planner and client. Research efforts have been focused on new tangible media for intuitive interaction between the user and the system. Examples of such media are BenchWorks/Sandbox from Seichter, iCube from Jeng and Illuminating Clay from Ishii et al. [2-4]. For building management and planning, visual representation should be supplemented with data about the existing buildings, new buildings, renovations, refurbishments etc. The interface used to access these data should be easily accessible, with no explanation necessary, since the system is used and operated by people with low technical skills.

In this article we describe a building management and planning system that was developed at Eindhoven University of Technology and applied for the future development of the Eindhoven campus. In this system the latest visualization, data management and interface techniques have been applied. It resulted in an innovative and unique system to which users responded very positively.

The outline of the article is as follows. First we describe the original ideas of the board and our interpretation. In the next section we describe the functionality of the system and the interface. The system parts are explained in detail in the implementation section. Finally, in the discussion section, we will elaborate on our experiences as we further developed the use of some of the technologies.

2. THE TU/E CASE

Five years ago the Dutch government decided that the universities would become the owner and thus the manager of their own building property. As a result, building management became part of the whole financial management of the university, along with research and education financing. A database system was set up at Eindhoven University to collect all relevant building data, and plans were made for renovation and
refurbishment. To discuss and convey these plans with the university community and with the legal authorities, the university board used slide presentations and a wooden scale model of the complete university campus. The scale model was used quite frequently, because it was located near the board’s office. The model proved to be an easy and helpful means of explaining to visitors how the university is organized.

A considerable portion of the building stock was in need of major renovations. Therefore, the board felt it was necessary to develop a more adequate method to discuss and convey these renovation needs. They wanted a permanent exhibition space in the vicinity of the board’s office to show why the proposed renovations were necessary, what the content of the renovation plans were, and how the plans were to be executed.

3. VIRTUAL MAQUETTE DESIGN

3.1 Functionality

The initial proposition was for a new scale model in combination with a slide show presentation. After some discussion we proposed a set-up that was quickly dubbed ‘The Virtual Maquette’.

In our discussions with the Facilities Management Department we defined the following parameters:

1. Like a traditional scale model, the Virtual Maquette should provide an overview of the university campus. From the actual use of the wooden scale model we concluded that top views would best serve this purpose.

2. For each building, the available data such as department, floor area, etc. should be accessible from the scale model. Intuitively, while discussing the scale model, we found out that attendees pointed at specific sections or buildings on the site. We also knew that information about building data (e.g., floor area) was available through an existing database. We concluded that a link between the buildings in the model and the existing database should be created.

3. An exceptional feature of the Virtual Maquette is that it should show the history, the present and the future of the buildings on the university campus. Some information and images about the history of the campus were available in the building database and the drawings of the buildings from the archive. Future plans only existed in reports with very global outlines of the architectural consequences. We concluded that a timeline could be used to organize this information.

The Virtual Maquette that we developed is based on a digital 3D model and utilizes a desktop projection and vertical screen projection. Plan views are used to explain where departments like Architecture and Chemistry are located on the campus and where other facilities can be found, such as the student sports center and the clean room labs. Zooming in combination with panning of the digital model lets the user focus on the complete...
campus, a section of the campus, or one specific building. Additionally, the Virtual Maquette allows for a virtual walk and a bird’s-eye view, which contributes significantly to the understanding of the campus plan. A link between the building objects of the model and the database helps users retrieve various kinds of information about a building as needed. Data are retrieved from the existing building database and displayed on a separate, vertical screen. A timeline and corresponding digital model can be operated by the user to show the state of all buildings at that time. In complement to the timeline, overlay color is used to indicate the maintenance state of a building. Buildings projected to be built are represented by abstract boxes. The implementation of these functions is discussed in Section 4.

3.2 Interface
The interface of the Virtual Maquette will support: (i) zooming, (ii) panning, (iii) camera navigation, (iv) linking to building database access and timeline, and (v) dynamic model display.

To create a robust and easy to operate system, it was decided not to use a windows/mouse-interface. Rather, the interaction would occur through a virtual model and the use of intuitive physical devices for operations and manipulations. In Computer Aided Architectural Design (CAAD) research, augmented reality techniques have been successfully applied for various applications, but to our knowledge not in a building management setting.

In the Virtual Maquette, the virtual model is extended with functions that can be operated using simple devices, which are located and identified through infrared tracking. In our search for technologies allowing for direct manipulation, we first looked into the possibility of using large-scale tablets or drawing boards. Tablets are developed for digitizing, lacking real time tracking functionality. Thus they were not found appropriate for our situation. Drawing boards are available up to A2-size but most importantly, they can only recognize one device (i.e. pen) at a time. We could not find at that time a commercial solution that supports multiple devices operating simultaneously in a single environment. After careful study of the situation, we concluded that infrared detection could be used to provide this functionality.

4. VIRTUAL MAQUETTE IMPLEMENTATION
4.1 VM-Hardware
The Virtual Maquette consists of two projectors, one projecting onto a vertical screen and one projecting via a mirror onto the horizontal table (Figure 1).

The images are rendered from a single 3D model. The top view in the horizontal plane is in fact a perspective top view that supports zooming and panning. Panning to the boundaries of the campus area will show the...
facades of the buildings. Users experience this effect as natural, and it provides an extra cue of the viewpoint position in relation to the centre of the model. The dimensions of the desk were determined by the resolution of the image that was acceptable, the distance between the ceiling and the desk, the size of the mirror, and the projection angle of the LCD projector. Some factors were incompatible with one another. These were balanced to find the optimal solution, which will be explained in the discussion section.

The vertical screen is a see-through projection screen with a mirror to save space behind the vertical panel (Figure 1). Standard PC hardware with a graphics accelerator card is used for rendering the two images in real time while navigating the model. For software maintenance a wireless keyboard and mouse are available in the drawer under the desk.

In the ceiling there is a hole for the projection on the desktop and for the infrared camera with infrared leds around it (see figure 1: right). The infrared leds illuminate the desk and the manipulation devices on top of the table. The manipulation devices are called Brick Elements (BELs). The BEL seen in figure 2 is shaped like a small paddle, but the BELs can have any shape. Each BEL is tagged with one or more pieces of foil that reflect incoming light back in the direction of the camera. The shape of each foil is unique, thus allowing for recognition by the camera. For example, panning and navigation is accomplished by manipulating a specific BEL with a tag on both sides. At start up, the plan is completely zoomed out. Through the projected menu (Figure 2) the zooming level is set by placing a BEL on the image of one of the three zoom level buttons on the menu. The timeline bar is projected at request by placing a BEL on the options button (#4 of the projected menu in Figure 2). Then a specific year in the past or future is activated by placing a BEL on the desired spot on the timeline. In our system, up to 5 BELs can be recognized concurrently, allowing control of camera, pan, zoom, building information, and menu. Over each recognized
BEL, the system projects a symbol corresponding to its functionality, e.g. a camera, information sign, etc. For clarity, the system is projecting an arrow over the BEL (Figure 2).

4.2 VM-Software

The Virtual Maquette consists of two major components, namely the VM-Viewer and the BEL-Tracker. The VM-Viewer was implemented using the Open Scene Graph software library [6]. The viewer renders the images of the 3D model, one from the top view for the plan on the horizontal desk, and one from the camera view position on the vertical screen. In the horizontal view, menus can be projected in overlay on demand and the symbols are projected over the BELs. In the vertical view the building data can be displayed in an overlay-window. A start-up file specifies the 3D model to be loaded and the initial settings. In the future this file will be used to select from a list of projects.

The BEL-tracker software is an adapted version from a previous project and is discussed in full detail in Ref. 7. This software scans the camera image for tag shapes such as a rectangular tag on top of the BEL in Figure 2. When a tag is recognized, the related function is processed, and the accompanying symbol is displayed over the BEL (Figure 2). How the system interprets a command depends on the state of the system and the location of the BEL. For example, the BEL in Figure 2 can be placed on one of the projected zoom buttons-site, section, building. The BEL tracker software is entirely driven by the VM-Viewer. For maintenance a windows/keyboard/mouse interface is activated.

4.3 VM-Model

The model of the campus is constructed using standard 3D modeling software. As typical in VR models, a balance must be found between too much geometric detail with poor system performance and too much texture mapping with poor visual representation. Each building of the 3D model has a unique ID that is related to the ID in the building database. The building database, managed by the facility management department, contains a picture and attribute data for each building. A special program was
developed to export the relevant data and transfer it into a so-called building passport. The passport is projected on demand as an overlay on the vertical screen, by putting a BEL on that building [Figure 3]. An example of the building passport consists of a photo of the building and the most essential data, namely usage, number of floors, floor area, address, and technical state.

The future plans of the buildings on the campus are described in a XML file. Each building is in a specific technical state during a specific period. The states are: in good condition (no color), renovation needed (red), under construction (yellow), renovation ready (green), and not part of university property (blue). When a BEL is used to select a specific time period (e.g. 2005-2007) from the overlay-menu, the system displays buildings as per how they were, are or will be during that time period [Figure 3]. The color is rendered by filtering out the complementary colors.

To speed up modeling of trees during the model loading, a predefined symbol is replaced by a billboard tree model. As billboards only appear correctly when viewed from the ground plane, an extra plane was added with a tree image from the top. The sizes of the trees are determined randomly, creating a more natural effect. Some dynamics were added to the model, such as moving cars and smoke from the central heating facility’s chimney, that are very much appreciated without causing distraction.

Model maintenance occurs through 3D model updates, renewed building database conversion to building-passports, and XML file editing for changing the building management plans.

5. DISCUSSION

On the opening day of the new exhibition space, the Virtual Maquette was used by members of the university board and facility management department. University guests stood around the table while a board member or facility manager explained the organization of the university, building facilities, renovation plans, etc. Initially the university employee operated the system through the BELs, but many guests liked to experience the BEL interface themselves. Because there are 5 BELs, they felt invited to pick one up and operate the Virtual Maquette. Most people are already familiar with Virtual Reality models, but the BEL was a novel interface to...
access the building management information. From the shape of the BEL and the projected symbol, the functionality was easy to assess. Without any further instruction, members started to navigate their way through the model. When they stood around the table they could not reach the entire model, and this forced them to coordinate the (dis)placements of the BELs. This stimulated discussions over the planning of the university campus.

The exhibition room is located in the middle of the building without direct daylight, which makes the LCD projectors produce bright images. It also prevents interference with infrared light coming from outside. Nevertheless, small changes in the armatures turned out to have an immediate impact on the BEL-tracking. Very subtle dispositions of the projectors, the desk or the vertical screen also lead to re-calibration of the BEL-tracking component. The main challenge users faced was that the system did not recognize the BEL when it was covered intentionally or unintentionally (usually by hands).

Technical challenges in designing the system resulted from the dimension of the table in relation to the intensity of the LEDs, the projection angle of the LEDs, and the viewing angle of the camera. Initially the intensity of the infrared light near the borders of the desk was too low. This caused the BEL-tracking component to lose track of the BELs. The limited projection angle of the infrared LEDs forced us to use two rings of LEDs around the camera in order to cover the whole table. A lens was placed in front of the camera to capture the image of the whole table.

A computational processing compromise was achieved by balancing the accuracy of the location calculations with the image updating frequency. The consequence of this compromise is visible when using the camera BEL. If the BEL is resting on the desk, then the vertical screen is displaying the camera view, but sometimes the view is not completely stable. If the camera is moved, then the projected camera symbol will follow the BEL, but it will always be a little behind.

Beyond the context of this paper, the introduction of the Virtual Maquette brought about many ideas for new applications. A straightforward extension of the system is the addition of visual and data information about the interior of buildings. Another application involves the development of a design system for urban designers. Virtual objects could be tied to information like building mass, green spaces and infrastructure. This would be easy to navigate using BELs. Additionally, GIS data could be used to supplement and assess urban design plans according to various environmental conditions and regulations. Finally, BELs could also be used in a gaming system for planners, tapping into the collaborative effect that is triggered by the BELs when people are gathered around a Virtual Maquette table. The system would be extended with MAS technology, for example, to implement the behavior of partners in the planning process that are not physically present. GIS tools would be used to analyze the effect of decisions and to visualize the consequences in terms of urban plans.
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References