Put on Your Glasses and Press Right Mouse Button

AR-Based User Interaction Using Laser Pointer Tracking

Christian Tonn ¹, Frank Petzold ¹, Dirk Donath ²
¹, ² Bauhaus University Weimar, Germany
¹ http://uni-weimar.de/jpai, ² http://infar.architektur.uni-weimar.de
¹ christian.tonn@archit.uni-weimar.de, ² frank.petzold@archit.uni-weimar.de
³ Dirk Donath: donath@archit.uni-weimar.de

Abstract. Activities in the building industry in Germany concentrate increasingly on a combination of renovation and new building. A prerequisite for computer-aided planning in the context of existing buildings is both the use of on-site computer aided techniques and the integration of all professional disciplines in an integrated information and communication system. How will computers be used on site in the future? Which equipment will be needed? An ongoing interdisciplinary research project undertaken jointly by the faculty of media and the faculty of architecture is investigating methods and techniques for the computer-aided support of the design process with and within existing buildings. The aim of this project is the development of a practice-oriented toolbox for the architectural design process based on SAR (spatial augmented reality). This paper focuses on Augmented-Reality based user interaction on site using laser pointer tracking. The project is funded by the German Research Foundation.

Keywords: Augmented Reality, Design Support, User Interaction.

Designing and planning in existing built contexts

The focus of building activities in Germany is characterized by a mixture of new building and renovation work. After the period of expansion of the built environment in the last 20-30 years, a process of consolidation and renewal of existing building stock has begun. A variety of factors contribute towards this development, e.g.

- Dwindling population figures are leading to a decrease in demand for living space
- Population drift away from the former industrial regions
- New approaches to working, telework, decentralized services etc. have reduced the need for dedicated production spaces
- A steadily increasing need to renovate existing buildings

Since the early 1990s, the focus of planning activities has shifted away from new building to renovation and building within existing built contexts. More than half of all building investment is in the renovation sector and this proportion will continue to rise (Hommerich, 2005). Building in existing built contexts is becoming ever more important and this looks set to increase still further in the coming years.
In contrast to new building, planning within existing built contexts necessitates a more complex interaction with the existing building substance and infrastructure and their respective special requirements. Not least, the actual presence of the building including an analysis of its history and changes made during its lifetime are a central aspect. The existing building substance is in all cases the basis for the design and planning tasks that follow.

**The current situation of Computer Aided Design**

A look at current computer aided systems used in day-to-day architectural work and an empirical examination of commercial computer-assisted planning software and IT-solutions reveals a gap in the (possible) IT-support for the design and planning of existing buildings. The current software and hardware market in this field is characterized by a variety of individual products, mostly adaptations of CAAD-systems, specific computer-supported solutions already available for new building or else adaptations of products from other fields, e.g. VR/AR supported design in the automobile sector or SAR applications (Bimber and Raskar, 2005).

The ‘Spatial Augmented Reality for Architecture’ (www.sarc.de: May 2008) research project aims to investigate and develop the conceptual and technological foundations for the ad-hoc visualization of interactive three-dimensional data on arbitrary surfaces in real-world indoor environments using a mobile hardware setup. This includes the design of a practice-relevant software concept and the development of prototype systems to support the architectural design and planning process within existing built contexts.

A focus of the project is to develop solutions that support the architectural design process in existing buildings, based upon the new mobile projection technology. Using commercially available video projectors and a digital video camera, the projection is corrected in real-time to compensate for the colour and the geometry of the underlying surfaces. The technology makes it possible to provide both purely immersive virtual environments as well as to augment real situations with additional virtual data to
show changes in the surfaces of objects. An important aspect that contributes to user acceptance is the ability to interact. To test this, we have developed a custom-built pan-tilt-zoom camera for laser-pointer tracking in arbitrary real environments (Kurz et al., 2007) (see fig. 1) which is a prerequisite for developing systems that can support the architectural design process in real-world environments. Here we are talking about the ability to interact with and within existing buildings at a scale of 1:1, and the support of design and planning processes at true scale (see fig 2).

The software framework

To manage all the hardware and software components, such as projectors, cameras and applications, we opted for a distributed software architecture based on a communication framework (TCP/IP) for linking networked architectural applications. A central lightweight server (called server 4+) manages a database, which stores the raw architectural data (such as geometry or surface properties) and can be accessed by clients through shared software kernels (see fig. 3).

The different clients all access and save to the centrally stored building data. Application clients provide architectural functionality, such as the tachymeter-based, photogrammetry-based, or sketch-based geometric surveying of building structures, colour and material sampling or modelling and inventory management (Petzold and Donath, 2005). These clients represent a selection of working tools that architects commonly use – although as yet only desktop-based visualization and interaction is supported for many of these.

To enable projector-based augmentations, individual service clients and kernels have been developed and integrated into this system. They provide specific functionality, such as real-time image correction for projections onto complex surfaces, projector-camera calibration, and synchronization management between different devices (see fig. 4). This framework (software architecture) allows an application to be used on a ‘traditional’ desktop PC or alternatively directly on-site, which we will describe in more detail in the following section.

The input device

As part of the research project, we developed a laser-pointer tracking technique that utilises a Pan-Tilt-Zoom camera (see fig. 1), which enables the laser pointer to be used as an input device in architectural environments (Kurz et al., 2007). A zoom camera...
captures the bright point of the laser pointer on the surface of the building and its position in 3D-space then calculated from the dimensions of the room, which are known. If the point moves outside of the zoom-camera’s field of vision, its movement is either continued automatically or its position is determined using a second fish-eye context camera. In initial pilot testing using the laser-pointer tracking system, gestures were used to activate particular functions, for example a ‘time gesture’, where the point remains on the same spot for more than 3 seconds, was used to activate the distance measurement function at this point. In practice this proved to be a little too imprecise – it’s difficult to hold still for so long. One solution is to add buttons to the laser pointer.

For this we chose to use a Nintendo Wiimote®. In addition to several buttons, this device also has a movement sensor, an IR-camera and Bluetooth interface. In addition, WiiUse, the freely available C++ control library (Michael Laforest 2007, http://www.wiiuse.net/), made it possible to instantly use the devices features for our own purposes. The wireless Bluetooth connection also makes it possible to move around freely within a radius of approximately 10 metres, which is sufficient for our purposes. A further client was developed and integrated into the software framework that allows other application clients to access the Wiimote® functionality. In the end it proved easier to dismantle the laser pointer and add this to the Wiimote® rather than adding buttons to the laser pointer (see figs. 5-6).

The on-site interaction concept

Working directly on site with the building substance around one is in certain respects fundamentally different to working at a desk and screen. When working on a CAAD-model on a 2D-display, one has an on-screen user interface with menu bar, toolbars and palettes, and one or more views of the CAAD model. Unlike the screen and desktop, when working within a building, the display surfaces are themselves a section of the architecture itself, which can also have a complex surface geometry. There is no frame around the screen, and the Start-Menu in the bottom left corner disappears among the overlay of projections.

Working on site also places new demands on the presentation quality and on interaction. When one works at a scale of 1:1, one also wants to experience the design, colour and materials of the space at true scale. Permanent menus and user interface destroy this illusion. Other forms of interaction such as gesture-recognition, speech input and context menus interfere less with the projection of the information.
Pie-menus

One possible approach to keeping the projected area free of distracting widgets is to use contextual pie-menus that appear as required. Context pie-menus are already familiar as they are used for browser plug-ins and in various operating systems. The available options and tools are arranged as icons around a circle centred on the dot of the laser beam (see fig. 7). By moving the laser pointer towards a certain point on the circle, the appropriate option is selected or a sub-menu pops up. With the help of text descriptions for the icons (see fig. 8), the designer quickly gets used to using the laser pointer to select a certain option. In this way, selecting a tool also helps the user to establish a laser pointer gesture.

According to Callahan et al. (1988), pie-menus are easier to use than rectangular linear context menus, as each option is the same distance away from the centre. One need only move the pointer into the right pie-section of the circle to select the function.

Application in the Software Framework

An ‘InteractionKernel’ was implemented as a software library that translates the various input data from the input device (laser-pointer tracker, Wiimote® or mouse) and displays the necessary UI element in the 3D CAAD model. All application clients in the software framework can use these libraries to enable them to be controlled remotely. The ‘InteractionKernel’ also controls which application client (e.g. ‘Colored Architecture’ or ‘Designing with Images’) currently has input focus in the network. The ‘InteractionKernel’ contains a central pie-menu from which all functions can be started that is accessed from the middle mouse button or the Wiimote® ‘Home’ button. This menu provides access to all functions in the application client and the option to switch to another application client. The pie-menu also serves to activate the interaction modes, the cursor symbol denoting the currently active function. The mouse or Wiimote® button applies the function. The following section describes a selection of possible on-site planning applications.

Colored Architecture

The software prototype ‘Colored Architecture’ (CA) was developed to support the design process for colours and materials (Tonn 2005 and Tonn 2008). The tool addresses the deficits of digital colour and material design and supports digital planning with colour and materials from the initial design, through the planning phase to specification. The digital support of colour and material design in CA uses and adapts existing strategies, instruments and representations, e.g. alternative variants, colour studies and colour relationships such as harmonies and contrasts. To
reliably assess and evaluate the results of colour and material choices, integrated radiosity visualisation is employed as it is able to represent interactions between different surfaces such as reflections.

The following examples show work undertaken in the windowless ARVis-Lab at the Bauhaus-Universität Weimar. The hardware setup consists of two wide-angle video projectors mounted on the ceiling (see fig. 9), the Pan-Tilt-Zoom camera (see fig. 1), a computer that drives the projectors and a mobile laptop on which the application clients run. The pie-menu can be used to start the different functions of the ‘Colored Architecture’ software prototype (see fig. 7). In addition to a drawing function that can be used, for example, to trace elements on a wall such as a crack or damages (see fig. 10), and a measuring tool (see figs. 14-15), a number of colour design functions are available. By way of example, a colour picker context menu has been implemented in order to be able designate the colour of surfaces or areas thereof on site at true scale (see figs. 11-12).

Designing with Images

The ‘Designing with Images’ software prototype allows one to capture optical impressions and to work with them in the design process (Schneider et al., 2007). Typical approaches to designing with images in this way are most well-known from image editing programs for the creation of photomontages. These are currently limited to two dimensions, but by extending the same principle into the third dimension, collages can be experienced spatially. Planning with images and photos allows the architect to compose photo-realistic spaces in the early phases of the design process and is especially useful for interior design, where photorealism is particularly desirable (see fig. 16).
The images can be inserted into the scene via drag and drop and adapt their position to the surfaces of the model. In a similar manner to traditional image editing programs it is possible to resize and rotate these images (see fig. 13). Where images are laid on top of other images they stack making it possible to design in layers. Furthermore it is possible to replace images, which makes it easy to rapidly compare different variants.

**Conclusion and outlook**

In this paper we have presented an augmented-reality based user interaction method that uses laser-pointer-tracking and is suitable for use on site. In addition to an ‘InteractionKernel’ for use in the distributed software framework, we have examined the use of pie-menus in different examples as a means of controlling and selecting functions. The integration of speech control for adding text is also envisaged. Similarly, an IR-marker tracking method is planned so that the position of the viewer can be determined for a 3D stereo projection.

A further aim of the research project is the development and integration of a motorised Pan-Tilt-Projector into the software framework. Through the use of a mobile projector, it should be possible to partially augment an entire room. The projection is then continually adapted to the rotation angle of the projector. A camera attached to the Pan-Tilt-Projector can follow the position of the laser dot of the input device so that through the shifting projection surfaces, the entire design of the room can be experienced.

Augmented reality technology opens up great potential for supporting the architectural design process. The ability to make and present design decisions at true scale on site ‘for real’ adds an entirely new dimension to architectural design (see figs. 17-18). The long-term aim of the research project is to take the practice of architectural design to a new level.
References