CAVE without CAVE

On-site Visualization and Design Support in and within Existing Buildings

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Activities in the building industry in Germany concentrate increasingly on a combination of renovation and new-build. A look at current computer aided applications reveals a serious lack of IT support for the whole architectural design process in and within existing buildings (e.g. building surveying, designing on site and the preparation of information for further use in later planning stages).

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 in and within existing buildings. The goal is to develop a hardware and software concept for a “design-toolbox” based on SAR (spatial augmented reality) and to implement aspects of this as prototypes.

This paper describes the goals of the “Spatial Augmented Reality for Architecture” project and discusses possible fields of application for SAR for supporting the design process in existing buildings from a user’s perspective. This paper presents the initial results of the project, the development of a cave-like hardware and software concept called “low-cost projection in room corners” and the description of the core concept based on a client-server architecture.

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Designing and planning in existing built contexts

Building in existing built contexts: the current situation in Germany

The focus of building activities in Germany is characterized by a mixture of new-build and renovation work. After the period of reconstruction following World War II and the 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: sinking population figures are leading to a general decrease in demand for living space, population drift away from the former industrial regions, and not least 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, C., Hommerich, N. and Riedel, F., 2005: Zukunft der Architekten – Berufsbild und Märkte. Eine Untersuchung im Auftrag der Architektenkammer Nordrhein-Westfalen, www.bakcms.de/bak/daten-dakten/architektenbefragungen/Zukunft_der_Architekten_Endbericht.pdf: Jan 2006).

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.

Computer aided design und planning for existing built contexts

The use of computers in architectural practice is widespread and complements traditional tools such as drawings and physical models. Computers can support the design process in three dimensions with the help of a building information model (BIM), however, the output devices are still generally ‘traditional’ 2D devices, such as screens or plotters.

Rapid technological advances are however enhancing the possibilities of architectural design, for instance three-dimensional VR and AR environments. Immersive and semi-immersive projection displays, such as CAVEs™ and workbenches are already used to support virtual reality applications in many professional domains, including the field of architecture. The visualization of data using such displays requires dedicated rooms for setting up non-mobile screens, and allows one to interact with purely virtual information only.

A look at current computer aided systems 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 or 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).

Spatial Augmented Reality for Architecture

The aim of the “Spatial Augmented Reality for Architecture” (www.sarc.de: May 2007) research project is to investigate and develop the conceptual and technological foundation for the ad-hoc visualization of interactive three-dimensional (stereoscopic) and two-dimensional (monoscopic) data on arbitrary surfaces in real-world indoor environments using a mobile hardware setup.

This is a prerequisite for developing systems that can support the architectural design process in real-world environments. In other words, the interaction in and within existing buildings at a scale of 1:1, and the support of design and planning processes at true scale (see figure 1).

The project is an interdisciplinary research project with two core areas:

1) Technological basis – core technologies
Projection technology allows the creation of images that are larger than the devices themselves and in locations that are impossible to achieve with other display technologies. With conventional technology, the need to erect projection-optimized screens nevertheless remains a major disadvantage. Visualizations projected without screens onto everyday surfaces are, however, fraught with difficulties. Projected images are often geometrically distorted, blend with the color of the background and portions are out of focus.

The focus of this research area is the investigation and development of a conceptual and technological basis for realizing visualizations in real-world environments – enabling immersive and semi-immersive virtual reality, as well as augmented reality implementations without the need for special display surfaces or permanent screen configurations. This includes:

- Data acquisition – the investigation of computer graphics techniques for extracting the real environment’s local and global illumination parameters,
- Rendering techniques – the development of real-time and non-real-time image correction techniques that enable the correct projection onto geometrically and radiometrically complex surfaces,
- Projector-based augmentation and illumination – the implementation of techniques that augment real environments with synthetic objects and simulated illumination effects,
- Basic interaction technology – the realization of fundamental forms of interaction (devices and techniques) appropriate to this new form of visualization.

2) Computer-supported architectural planning in and within existing built contexts
Based on the evolving core technology a second focal area is the investigation of new forms of interactive information visualization to support the entire architectural design/planning process. The projection technology enables one to project data in real-time onto almost any surface of an existing building, color-calibrated and geometrically rectified so that it fits the real context. The setup can be positioned freely, much like pointing a torch. 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.

The aim of this research stage is to develop a software concept, to implement selected aspects of the concept and then to evaluate these in real environments.

Research began with an empirical examination of existing computer-assisted planning software and IT-solutions in the architectural field and an analysis
of the “traditional” day-to-day work process. In addition, related fields such as product and automotive design were also examined.

From these a software concept was developed and individual tools developed as prototypes to provide support for the respective phases of the architectural design in and within existing building, for example:

- Support for the planning-oriented measured survey, such as the comparison of existing plans with the real situation (superimposition of plan and room), or the localized surveying of additional data (for instance verification of the model against the real situation, augmentation of the model with image detail and geometric information).

- Support for on-site design methods such as the rapid creation and assessment of design variants undertaken on site in the room in question. The technology enables new information to be superimposed and existing situations to be ‘cancelled out’. The real environment serves as the basis for planning. The design support can be loosely categorized into the immersive formulation of design intentions, and functions and on-site simulations that support decision-making processes.

- Support for interactive presentation using a low-cost CAVE™-like immersive stereoscopic projection in room corners for the interactive creation, display and presentation of design intentions and different types of architectural models.

### Low-cost stereoscopic projection in room corners

Immersive display projections, such as CAVEs™, have been used for many years to support the design process in fields such as the automotive industry. These require specialized, large and immovable setups, and allow one to interact with purely virtual information only. In the architectural environment, CAVE™ solutions allow the creation and display of building and urban contexts as well as 1:1 simulations. The technology required is both expensive and dependent on immobile hardware solutions.

A two-sided stereoscopic forward-projection served as an initial test platform for our project (see figure 2). Instead of using specialized projection screens, two walls meeting at the corner of an ordinary room were used to create an immersive experience. In this test scenario, we used only planar white surfaces. Here the focus was to test and evaluate the algorithmic compensation of indirect scattering for immersive and semi-immersive projection displays (see figure 3; Bimber et al., 2006).

Surfaces need not necessarily to be white or planar – it is also possible to project images correctly
onto arbitrary existing complex surfaces, such as walls or curtains (see figure 4; Bimber, Emmerling and Klemmer, 2005). The projection onto reflective or transparent surfaces is as yet not practically possible (Wetzstein and Bimber, 2006).

“Low-cost stereoscopic projection in room corners” makes use of standard commercially available equipment, making the system both inexpensive and portable. Two ceiling-mounted 120Hz DPL projectors with front-mounted wide-angle lenses create a 6×2.2 meter image at a resolution of 1600×800 pixels. The image extends beyond the user’s field of vision and supports disparity-based depth perception of the presented content. An optical tracking system ensures that the projection is correct from different perspectives. The system uses techniques to compensate for secondary scattering effects.

The software solution developed allows the use of different sources, for instance VRML-Models or a video stream.

In this scenario the Quest3D serves as the architectural content client (see figure 5). Quest3D is a software package that can be used for virtual reality projects – architectural content means a walk-through through a building, the interactive visualization of design intentions, simulations or life-size design at a scale of 1:1. The visual programming of Quest3D (channeling) is easy to learn.

The Quest3D C++ SDK allows one to build “new” channels (see figure 6). A dedicated Quest3D...
channel was developed that renders two stereo-pairs and compresses them into a single 1600×800 image (see figure 7). This image is streamed from the application PC to the display PC, which decomposes the sub-images and projects them onto the walls.

**A Spatial Augmented Reality toolbox for architecture**

The concept of the system follows a modular principle. Different modules for information capture, design and planning can be combined as required. The individual modules form a continuous, extensible, flexible and in real-time dynamically adaptable system, which covers all aspects from the initial site visit to detail planning. Each tool was developed for an individual aspect taking into account its role and the requirements of the entire planning process. This concept was developed in an earlier research project “Collaborative Research Center 524” and adapted and expanded for this framework (Petzold and Donath, 2004; Donath, Petzold and Thurow, 2001).

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 figure 8).

The distributed architecture allows existing architectural application clients to access the functionality provided by new service clients. Shared libraries (called kernels) act as interfaces to the server and provide basic functionality for all clients. This structure makes the system extremely flexible and extendable.
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, color and material sampling or modeling and inventory management (Donath and Thurow, 2005; Petzold and Donath, 2005). These clients represent a selection of common working tools for architects – although support is only for desktop-based visualization and interaction. 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 figure 9).

The interaction between different clients and hardware components is described in the paper “Simulating the atmosphere of spaces – the AR-based support of 1:1 colour sampling in and within existing buildings” (also published in the conference proceedings).

**Future perspectives**

Future research will concentrate on the continued development of a mobile hardware setup, real-time algorithms for geometric and color correction, new tracking methods and a new means of interaction – the laser pointer interaction. In addition the implementation and evaluation of further architectural applications will be pursued, e.g. designing with images – Augmented Reality supported on-site trompe-l’œil.
References


