Augmented Reality Techniques for Design and Revitalisation in Existing Built Environments

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Abstract
Building activity in Germany is moving increasingly toward combined new-build and renovation projects. Essential for effective computer-aided planning within an existing context is not only the use of on-site computer-aided measurement tools but also an integrative cooperation between the different disciplines involved via an information and communication system. Interdisciplinary cooperation needs to be tailored to the integrative aspects in renovation and revitalisation work. Economic factors determine the viability of an architectural project, and reliable costing information is vital. Existing IT-approaches to this problem are not yet sufficiently exploited. In ongoing research at our university (collaborative research center ”Materials and Structure in the Revitalisation of Buildings”) methods and techniques of revitalisation are being investigated. A special branch of the collaborative research center is investigating possibilities of computer-aided building measurement and communication platforms for professional disciplines (www.uni-weimar.de/sfb).

The aim is to develop a general approach to the revitalisation of buildings.

This paper discusses possible application areas of AR/VR techniques in the revitalisation of buildings from the point of view of the user and are based on the real project “Cooling factory Gera”. Based on the necessities of revitalisation projects, technical requirements are developed. The project is funded by the Deutsche Forschungsgesellschaft (DFG).

Keywords
Augmented Reality, Architecture, Modernization, Measurment

1 Introduction

Like many other countries, Germany is in the process of consolidating and repairing its existing building stock. Future building activity is increasingly characterised by a combination of new-build, renovation, modernisation and revitalisation. More than half of all current building work are within and around existing built substance. The specific planning and realisation problems connected with revitalisation work have not been sufficiently researched and are rarely mastered in professional practice.

Reliable and informative documentation is an essential pre-requisite for planning with existing buildings. If documentation is not available, then building surveying, despite its cost, presents a real alternative for providing accurate plan information. The building must therefore be measured-up, either in its entirety, in part or for verification.

A look at current computer aided surveying systems reveals a serious lack of IT-support for surveying and the preparation of the collected information for further use in later planning stages.

The main problem of existing special-purpose software solutions used for individual sub-tasks in planning processes today is the absence of a common data model and standard interfaces. As current computer-supported information exchange are primarily geometry based, a danger is that the semantic connections between data are lost when transferring the information from one representation to another. A particular problem when it comes to surveying existing buildings is that no conceptual models exists for the description of building stock, its condition and life-cycle properties. (Donath et al. 2000a)

2 AR & VR within the planning process

2.1 Objectives

The purpose of the project is the conceptional design of a computer-aided system for the capture, management and efficient integration of different types of data and to make these available in a flexible form for later planning tasks.

Planning tasks in existing buildings can be roughly divided into the following steps:

- measurement / capture
- conceptional design
- implementation

Architectural surveying and measurement means the structured gathering of building-related information. Even during the initial capture phase, the data is simplified and reduced to a level appropriate for its further usage.

In addition to the geometric information, other formal (numerical), informal (text, pictures, video-sequences, sketches etc.) and relational (presumed structural interdependencies) data is gathered. Acquired data is considered to be imperfect. Existing techniques like tachymetry, photogrammetry, manual measurement, vectorisation, photography etc. each focus on individual aspects to which they are best suited. Considered individually, these tools do not meet the demands of an ever-growing complexity of building tasks. However, an integrated and inclusive combination of techniques can lead to efficient results. Economic and efficient results can only be effectively achieved through an interdisciplinary approach and the combination of data capture techniques.

In contrast to planning new buildings, a survey is the basis for all further architectural and engineering planning tasks to do with existing buildings. Existing built substance is the authoritative guideline for every aspect of the design, and the design intention and constraints can be discussed with the client at an early stage.

Central to a successful realisation of a project is an effective communication between the different professional disciplines. Different representations of the building model have to be made available to the different parties. Changes that are effected by the specialist have a mutual impact on the whole model. The interdependent nature of this process requires a well-conceived, flexible data model.

The overall objective of this project is:

- the unification of different measurement methods
- a well-structured disposition and management of acquired data and
- the integration into a general model for revitalisation

making use of virtual and augmented reality as enhancement techniques for existing architectural, urban planning, geodesy and computer science techniques. Research and feasibility studies are used in the development of a concept.

The scenarios described here are based on combinations of approved methods of current research in AR/VR, including:

- on-site tracking with flexible, portable combinations of different tracking devices, i.e. GPS (i.e. MARS (Höllerer et al. 1999, www.cs.columbia.edu/graphics/mars), Azuma (Azuma et al. 1999), Image-based-tracking (Coors et al. 2000) CyliCon (www.siemens.de) or ARCHEOGUIDE (Stricker et al. 2001)etc.
- Indoor positioning, i.e.. Active Badge system developed at Olivetti Research Labs in Cambridge or RF Tracking at TimeDomain "PulsONTM Technology - Time Modulated Ultra-Wideband (Scholtz 1993)
- wearable computing (Behringer 2000)
- 3D-input devices (reflectorless tachymetry devices (www.leica.com), Finger-Tracking (mevard.www.media.mit.edu/projects/wearables/augmented-reality.html), GPS Networks Leica ControlStation (www.leica-geosystems.com/gps/product/controlstation.htm)
- speech input (hci.rsc.rockwell.com/)
- HMD-based display devices (video-see-through, optical-see-through etc.) (Kiyokawa 2000)

The individual systems and their combination potential are not as yet tested in practice. Their practical application in the varied and complex conditions in existing buildings needs to be investigated with regard to their suitability:

- unique building sites
- application outside of laboratory settings
- large range capability and ability to deal with unpredictable surroundings/ environments
- minimal calibration requirements (Donath et al. 2000b)

2.2 Fields of application and special issues

AR techniques can be usefully applied to the following work areas. These reflect the conceptual structure of AugPlan:

- to facilitate cooperation and communication between professionals in the planning process (i.e. the communication and preparation of filtered information)
- the display of hidden/not directly accessible information
- surveying, measurement and information capture on-site
- the creation and editing of further building-relevant information

AR techniques are particularly suited for working with existing building, more so than in currently investigated AR application areas, due to the requirements of the specific real situation, i.e. the existing buildings and their surroundings:

- each situation / site is unique
- specific physical conditions are often adverse (cold, wet, dirt...)
- the location is always elsewhere (remote)

2.3 Scenario 1 – Building surveying on-site

One can distinguish between two primary approaches to on-site building surveying:

a) The verification of existing planning documentation

The basis for verification, specifically geometric verification, are existing 2D drawings or 3D models. The surveyor sees the existing data in a see-through overlay. Using geodetic input devices, manual measurement and correction, the actual survey results can be superimposed on the existing model, and the existing virtual model can therefore be 'synchronised' with the real-world situation. The surveyor works with a synthesis of measuring instrument and input device/user interface for the virtual model: the tachymeter measures distance, the same system allows vertices, edges and faces in the virtual model to be moved to match the live picture. The AR/VR-software system assists with suggestions based on edge-detection-techniques. (Figure1, Figure 2)

The concept envisages a system similar to that of the prototype system CyliCon by Siemens (Navab et al. 2000a):

- the combination and integration of existing measurement techniques (tachymetry, photogrammetry, manual measurement)
- the use of topological base models that can be instanced and substantiated on-site
- the use of devices and control mechanisms in combination with AR display-methods, for instance the direction of motorised reflectorless tachymeter

The geometrical information should be augmented by simultaneous integration of additional formal, informal and relational data.

b) Partial or complete survey

Surveying from scratch is limited by the fact that only the bounding surfaces can be measured. Non-reflective tachymetry supplemented by photogrammetry and manual measurement represent to date the most efficient approach to geometric surveying. The surface topology is described by a series of single measured points on the building's surface. (Donath and Petzold 1997a, Donath et al. 2000c) The captured data is constantly being checked against the real situation by overlaying the captured model with the image-data from a camera. By doing so, the surveyor is able to verify the developing virtual model on-site. Corrections can be applied immediately.

A particular aspect of our concept is the direction of measuring devices, in particular the reflectorless tachymeter. (Figure 3, Figure 4)

Figure 3. Control the survey devices. *Figure 4. Corresponding of user and survey devices.*

The classification of structural components, and of structural coherence and interdepencies is an important aspect in surveying. A software-system could assist the user by providing already sampled

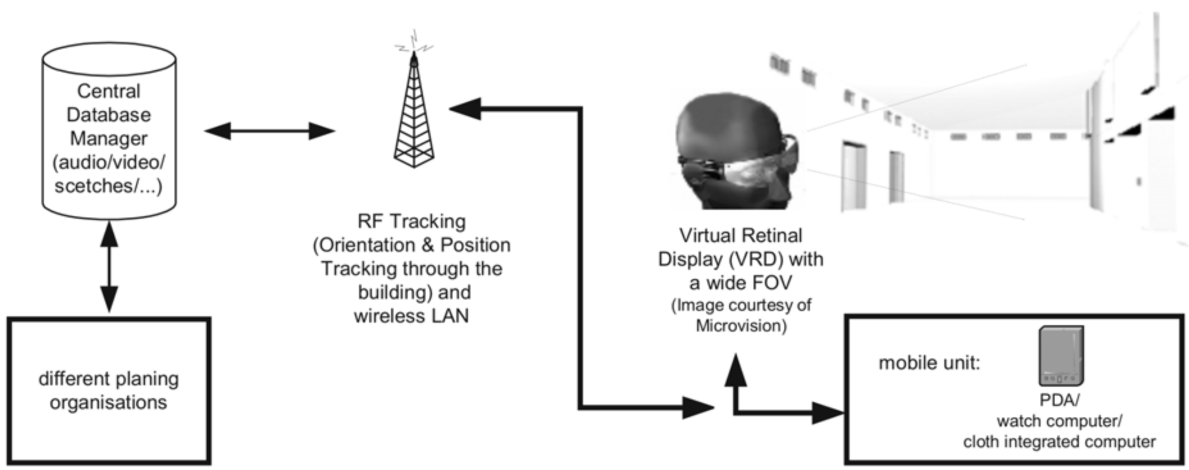

Figure1. The concept of an vision system architecture.

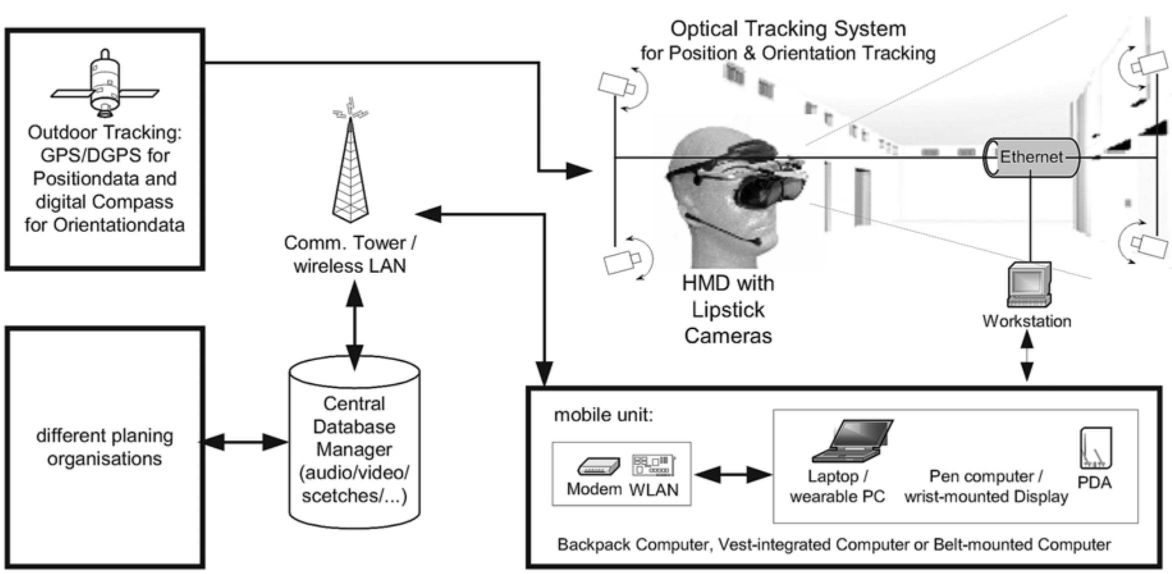

Figure2. The concept of an current system architecture.

visual spatial information for comparison, so that structural relationships can be recognised and determined during the on-site survey itself.

Additional information, for example for recording crack-lines in walls and other elements can be added to the same system without the need to change medium or input device (Donath and Petzold 1997b):

- hand drawings
- recording of images
- speech notes
- manual sketches

By displaying relational data from other parts of the building or from a knowledge repository of buildings of the same type, structural dependencies can be perceived immediately on-site instead of being gleaned from in plans drawn up in the later in the office. The data can therefore be extended beyond the purely geometrical and can be

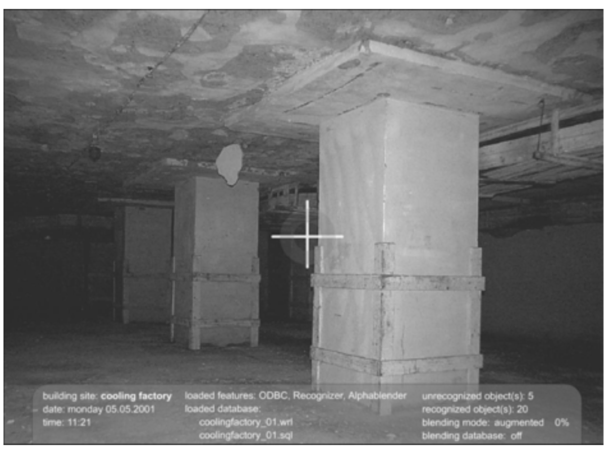

Figure 3. Control the survey devices.

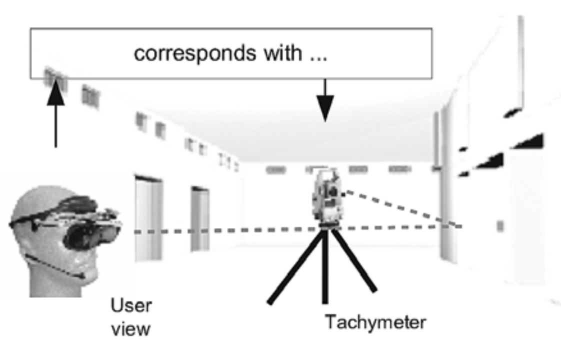

Figure 4. Corresponding of user and survey devices.

considered within a data-structural context at an early stage of the analysis. (Figure 5)

The surveyor can be further assisted through the use of overlays displaying further levels of information such as technical construction, for example re-inforcement plans, wall structure etc. (Navab et al. 2000b) (Figure 6)

2.4 Scenario 2 – AR/VR assisted architectural design

A major opportunity presented by the use of AR/VR techniques in architectural design is the ability to work at real-scale in all phases. Lay-people involved in the building process, such as clients or prospective purchasers, often have difficulties understanding and translating 2D-architectural representations, scale-models or even screen-based computer-aided architectural representations into real three-dimensional spatial situations. (Figure 7)

AR/VR-techniques enable real-scale representations of the existing situation to be communicated and augmented by further information, for example traffic simulation or lighting studies. Misunderstandings between planner and client can therefore be better avoided, which otherwise might normally lead to additional costly measures and time-delays.

- Amt (Regenbrecht et al. 1998) Factors influencing presence in virtual environments: interaction, self-movement, animation, and illusory interaction.
- VRAM (Donath et al 2000d) - VRAM serves as a testbed for three dimensional user interface (3DUI) techniques to allow better navigation, orientation, and modelling within virtual (architectural) environments.
- PlaneDesign (Donath and Regenbrecht 1998) Programs for sketching and simple design tasks in VR.
- TAP (www.technotecture.de/projects/tap), TAPserver is a part of the TAPframework, a distributed virtual reality system. TAPserver is the distribution point for all applications within TAPframework. All connections are handled and bundled by this piece of software. TAPframework is a multi-platform, multi-threaded, multi-purpose API for developing virtual reality software for architects. The software is provided “as-is” and with source code.
- Jolanda (www.spatialknowledge.com). Jolanda provides a VRML-97 browser for VR environments using HMD, Stylus and Polhemus-Longranger. Support for further input/output devices is possible and envisaged (Fasttrack FOB, stereo-projection).

The impact within the larger urban environment can also be judged more easily from a real (human) scale. AR/VR-methods also enable design variants to be created quickly and be discussed with the client on-site, often a time and cost-intensive process when using conventional techniques.

2.5 Scenario 3 – AR as a communication-platform in the building process

An integrative approach to renovation and revitalisation work involving all professional disciplines via an information and communication platform is an essential aspect of computer aided planning. The planning process is characterised by:

- ever-growing complexity and scale of projects
- increasing specialisation of individual disciplines and supporting applications
- world market globalisation (virtual organisations)

Seen within the context of teamwork that is becoming increasingly independent of place and temporal location of the participants, the need and importance of a computer-aided communication and information platform becomes obvious.

The main requirements for these systems are:

- the establishment of an efficient, error-free data and information exchange
- ensuring communication and co-operation between all participants (Willenbacher et al. 2000)

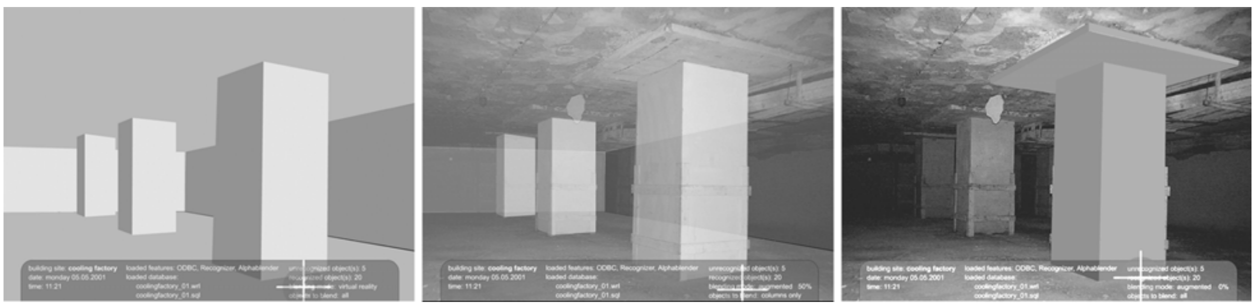

Figure 5. Emphasize information's.

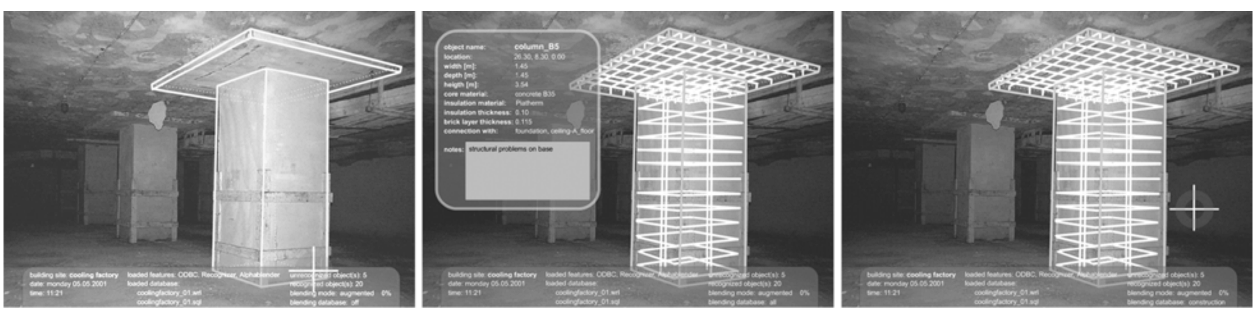

Figure 6. Edit database.

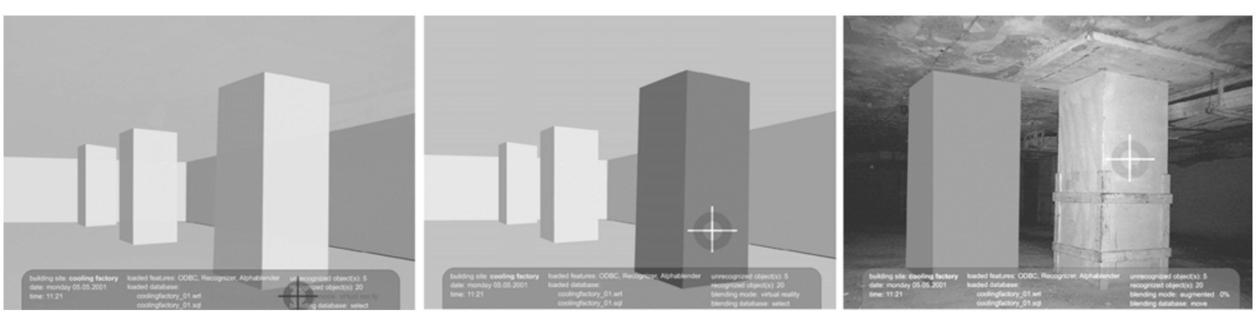

Figure 7. Design into a real context.

An efficient data and information exchange requires the setting up of a unified communication and cooperation platform. The quick commented 3D-sketch is still a frequently used means of communication between professionals, but is difficult to communicate and understand these sketches in computer form as intuitively as the pen-and-paper counterpart. The provision of context-sensitive sketches made possible via VR/AR (for instance overlaid on real world three-dimensional situations on-site) could represent a major improvement in communications between spatially separated planning participants.

3 Conclusion and future works

The scenarios presented in this paper should be understood as a possible integration of application research into VR/AR-techniques in building and planning. Future research will concentrate on the development of a system specification and a prototypical implementation.

The scenarios illustrate both the considerable technical requirements involved as well as the broad application possibilities for AR and VR-techniques in the architectural planning process for existing buildings.

AR offers the possibility of combining several tasks in one (different measuring techniques, digitising, mass and volume calculation and transfer to a facility management system) and to integrate separate organisational steps (survey, transfer to CAD, planning, structural calculation, etc.). Through the effective preparation and transfer of information it reduces time delays in information transfer and connects and collects relevant information at the salient point. Work can continue uninterrupted and data management and transfer can be achieved from begin through to the building in operation. An optimised provision of different information helps reduce planning costs as well as follow-on costs in facilities management and improves the smooth transfer of information.

The current situation in building practice emphasises the need to find solutions for improving and facilitating planning within the context of existing buildings:

- increasing complexity of building projects
- optimisation of the design and planning process
- increasing specialisation within the disciplines
- world market globalisation (virtual organisations)

The cooperation between different participants, disciplines and organisations and the integration of specialised applications into a heterogenous system environment for planning and decision.making within building projects becomes increasingly important.

In particular seen within the context of teamwork that is becoming increasingly independent of place and temporal location of the participants, the need and importance of a computer-aided communication and information platform becomes obvious.

The increased application and development of the techniques described in this paper could lead to projects with a variety of application areas:

- integration of overlay-techniques for quality assurance
- augmented reality aided assembly instruction for constructions workers
- passing on of acquired data to the later stages in the life-cycle of a building, i.e. facility management
- integration of acquired data into more general knowledge-repositories, i.e. building information systems

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