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The development of Augmented Reality as a tool in Architectural and Urban design

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TOPIC: ARCHITECTS IN THE 21ST CENTURY – AGENTS OF CHANGE?

Abstract:

The development of Augmented Reality as a tool in Architectural and Urban design.

Architectural representations consist of mediating artifacts utilising traditional techniques. These techniques have limitations and embody a large degree of abstraction. Consequently there is a need for interpretation and the representations can, instead of mediating, constitute barriers and obstruct communication.

This paper presents research on the use of emerging technologies for simulation and visualisation of architectural projects at the Oslo School of Architecture and Design.

Augmented Reality (AR) is a system for blending virtual models with real life settings, thus making it possible to experience proposed architectural solutions in full scale at the intended site.

The author argues that this technology will have a significant impact on, and applicability for, the architectural design process and the mediating of architectural projects.

Keywords:

augmented reality, architectural representation, visualisation, emerging technologies, architectural practice, architectural education, governance.

1. Introduction

Mediation of architectural projects has always been problematic.

The reason for this is that the available forms of representation can not simulate adequately the physical reality a project results in. Viewing the history of architecture one will find that the discussion on representation has been going on irrespectively of the technological means available.

My hypothesis is that Augmented Reality will help us achieve a representation that to a great extent will diminish the distance between representation and reality. The use of this technology as a mediating tool will in turn have effect on the architectural practice. It will not only be used to present the finished design of buildings, but also be part of the process for evaluation of design propositions with different levels of abstraction. Consequently this will be of significance for the architectural education since the students will be able to study their concepts and solutions on site and in full scale.

The traditional tools for architects are two-dimensional drawings of plans, sections and details. This is consistent with the prevailing practice for representation that was introduced in the 18th century, where one had the notion or understanding that value-neutral representations collectively constitute the total idea of the proposed project.

Communicating projects to lay people shows that this is not entirely true. Traditional representations embody both a need for abstraction and interpretation and can thereby be difficult to understand. Therefore they possibly mislead those not trained in the field.

In response to this, the drawings of architectural projects and urban design are today complemented with perspectives, text and 3D models, both physical and digital. Still there is a common problem of understanding both spatial qualities and the scale of proposed buildings and structures. As a result, project-owners, politicians, decision-makers and the public often have expectations based on their interpretation that differ from or exceed the qualities of the realised project in its context.

In addition to the immediate problems that can arise from miscommunication and misunderstanding of proposals, it can also pose a problem for the democratic process when decisions are made regarding our environment. The European Commission aims to improve governance and for urban design and planning governments have tried to be more transparent to ensure the right level of participation. In this context, methods for enhancing the possibility for the civil society to participate in the process of shaping our urban environment could contribute to the quality of local level governance.

The use of Virtual Reality has added a new dimension to presentations of planned structures and in many instances proven valuable for the understanding of projects. In a complete VR system all parts of a scene have to be digitally constructed, which requires extensive work for the making of the model and highly specified and expensive hardware for the regeneration of them. Screen based VR presentations can easily be distributed but as with an immersive system, orientation is not intuitive, the feeling of presence is hard to achieve and the problem of understanding scale is still not solved. That is, even though one moves through digital models that closely resemble a reality, they are experienced as scale models.

Augmented Reality, AR, is a further development of the technology and is understood as a combination of digital models and the physical world.

An AR system generates a composite view with a combination of a virtual model or scene and the physical, real life setting in which the viewer is located. The technology has until recently been expensive, resource demanding and requiring advanced knowledge in the field. Due to these factors the use has been limited mainly to military, medical research and other highly specialised applications

This paper will present ongoing research into the use of Augmented Reality in the development and communication of architectural projects and urban scale plans at the Oslo School of Architecture and Design.

2. Research participants

In 2003 the Oslo School of Architecture and Design, AHO, established a co-operation with Institute for Energy Technology, IFE[1], on research on the use of Virtual and Augmented Reality. IFE is in their research in close cooperation with the Yoshikawa Laboratory at Kyoto University, Japan.

The research concept described here has emerged from this multi-disciplinary collaboration between architectural education and research and nuclear research and development. In the nuclear field IFE has done research on and development of Virtual and Augmented Reality-technology for over a decade with their VR-technology applied in real world settings since 1996. This has been further developed amongst others through their involvement in the decommissioning of the Fugen nuclear power plant in Japan and simulation models for the Leningrad nuclear power plant in Russia. One main objective for IFE in their research and development has been to "see the invisible", to visualise radiation.

Their first test on Augmented Reality took place in a controlled experiment in the Halden nuclear reactor in 2002 where the objective was to show a 3D radiation distribution using Head Mounted Display. This has been further developed to allow real-time update of an AR model showing changes in radiation; thus enhancing the operatives' awareness of radiation and increasing security. Currently both NASA and ESA are investigating using this system and software to visualise cosmic radiation and for mission planning.

3. Augmented Reality System, a description of principles.

An Augmented Reality system consists in principle of these main components:

1. Software System and Databases
2. Position-registration System
3. Orientation-registration System
4. Display Device

3.1. Software System and Databases

The core of the augmented reality system is the software and database running on a portable computer. The database contains the 3D models to be viewed and their geolocation. The software position these according to the data retrieved from the registration systems.

Based on the data for location and orientation of the viewer and the digital model, as well as the optical field of view of the display device, the software superimposes or composite (*see 3.4 display device*) renderings of the virtual model on the display device. This is done with a real-time updated image of the objects which are within the user's field of view. When the user moves or changes orientation the virtual objects will remain in place relative to the physical environment and rendered correctly relative to the viewing direction. Virtual objects can be of static structures or animated and moving.

3.2. Position-registration System

The position-registration system is crucial to the accuracy and field of use of the AR system. Its purpose is to provide the system with the exact geo-location of the user so the virtual models can be positioned correctly according to this. Several different solutions exist, each with specific possibilities and limitations. For indoor use or in confined spaces one can use ultrasound, infrared systems or graphical markers with camera recognition. Common for these are the need for setting up the system which can be time consuming. For viewing large structures on site outdoors, the most effective and accurate solution today is differential GPS. It requires no additional installation and provides the system with real-time update that allows free movement by the user. This system is currently expensive, but in the future access to new satellite positioning systems such as Galileo will make the system less expensive.

3.3. Orientation-registration System

Precise and accurate combination of the virtual model and the real environment requires the system to provide data for the exact location and viewing direction and angle of the user. For head mounted display systems it is common to use gyroscopic sensors. In terms of quality these give results of differing usability; slow reading can cause lag in the update of the virtual objects in the image and drifting can occur due to the registration of relative changes in orientation. Inexpensive gyros can cumulate errors and require frequent recalibration. Inaccuracies in the readings will result in increasingly inaccurate positioning proportional to the distance to the object, which can render the system useless for the purpose. To a certain degree these problems can be compensated by software or introduction of additional systems.

3.4. Display Device

The display device is for viewing the Augmented Reality. According to the definition of AR by Ronald Azuma[2] there are several ways of viewing AR models, but here I will limit the description to Head Mounted Displays, HMD. These consist of two small screens mounted in front of the user's eyes.

HMD's are being developed but can already give a near to natural experience as they offer full freedom of movement and orientation.

One main solution has optically see-through screens where the user can see the physical environment with a superimposed image provided by the system. The other solution has screens that are not transparent. In this, cameras feed images of the surroundings to the AR-system which composite these with renderings of the virtual model. This gives the possibility to record or distribute the experience to others.

For both solutions the field of view and characteristics of the device need to be known for the system to generate images of correct scale.

3.5. The integrated system with differential GPS in a typical scenario.

Digital architectural models in 3D of industry standard format are transferred or translated to a database in an ISO standard format[3], currently ISO VRML97[4] or ISO X3D[5]. Geometry and rendering as well as geo-location and orientation are registered. The system requires only a digital model of the proposed structure or in some cases the adaptation to its immediate surrounding. On site the system retrieves models from the database, composite these with the camera-fed view of the physical surroundings and shows this on the screens of the Head Mounted Display in real time. The integrated AR system is portable so the user can move freely around experiencing the augmented model at will.

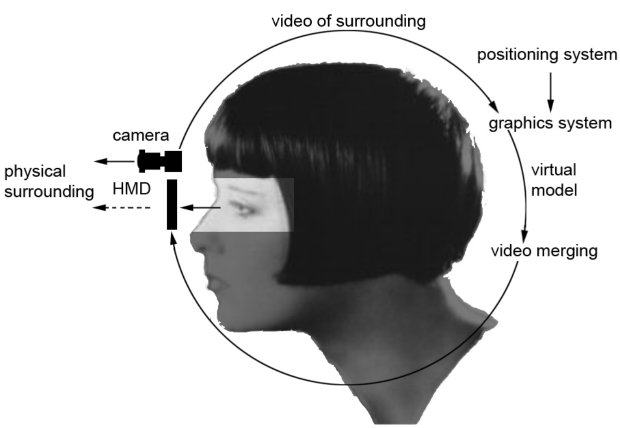

fig. 3.5.1, diagram showing principle of the system.

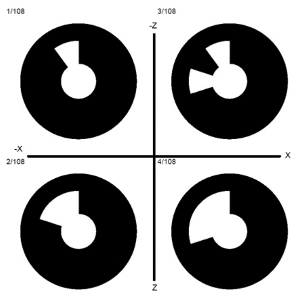

fig. 3.5.2, graphical markers.

Currently one can achieve sufficient accuracy with this system to experience the augmented reality with true position and no lag.

4. Research and development: Proof of concept.

The main research project on Augmented Reality is ongoing with a thorough verification of the technology and real life cases starting in May 2006. Preliminary stages have been investigation into technological solutions, IPR implications, roles of participants, investigation into financing, applying for funds through suitable research programmes and testing systems. Preliminary testing or "proof of concept" has been undertaken in three different settings with the objective to investigate specific questions.

The project has been revised and formulated on the basis of the experience from these.

Currently patent applications are being lodged, therefore this paper can only discuss use of AR technology in the field of architecture on a more conceptual basis without describing specific technical solutions emerging from the research.

4.1. Proof of concept 1; First test of outdoor system.

Early 2005 the first demonstration of viability was performed in Halden, Norway. Camera recognition of graphical markers[6] as positioning system was tested by virtually adding two storeys to the IFE MTO Laboratory building. This system with circular markers[7] is developed and was set up by Hirotake Ishii, PhD., Kyoto University. It was initially intended to be used in controlled environments indoors with models of a much smaller scale. The integrated AR system consisted of a helmet with two cameras, a Head Mounted Display and a portable laptop carried in a rucksack by the user. One camera was dedicated to marker recognition and the other to recording the view.

Minor problems such as sun glare disturbing the reading of markers were recognised, but the Augmented Reality model was sufficiently stable to determine the viability of the concept; the location was exact and the alignment with existing structures satisfactory.

The user was able to walk down the street facing the laboratory, see the virtual extension on top of the existing building and compare three alternative extension models.

fig. 4.1.1, proof of concept 1 : equipment.

fig. 4.1.2, proof of concept 1 : graphical markers on building.

fig. 4.1.3, proof of concept 1 : view of extension (image on laptop from HMD).

4.2. Proof of concept 2; Dynamic models and sound.

The second was done as diploma project by architectural student Halvor Høgset under my supervision at AHO in the spring semester 2005. The objective was dynamic AR models and virtual 3D sound; i.e. the virtual model is not static, but changing in shape and position in a scene which includes simulated, changing sound sources. The positioning was based on the same graphical markers, and during the semester Hirotake Ishii worked in close connection with him to solve technical issues.

In his project the student wanted to generate architectural form from sound and represent this as dynamic virtual models composited with a physical site with spatialised sound incorporated in the experience.

The composer Arne Nordheim provided him with the music, which he analyzed and treated digitally to generate controls for shaping, manipulating and animating virtual three-dimensional forms.

The result was a 10 x 10 meter indoor installation with the markers laid out as a ceiling above the user, in an optimal distance from a camera mounted on top of a helmet. By doing this he eliminated optical restrictions otherwise limiting the user's field of operation. The Augmented Reality showed different groups of changing and moving three-dimensional forms reacting to the music. The sound followed these in the virtual space and changed in strength according to distance from the user.

There was a large degree of technical issues regarding the development of the project and realisation of it. In the development of AR and research on this, implementation of dynamic models is new and advanced, which also is the case for spatialised sound.

In his project the student solved these and recognised inaccuracy problems that aided further development of the positioning system.

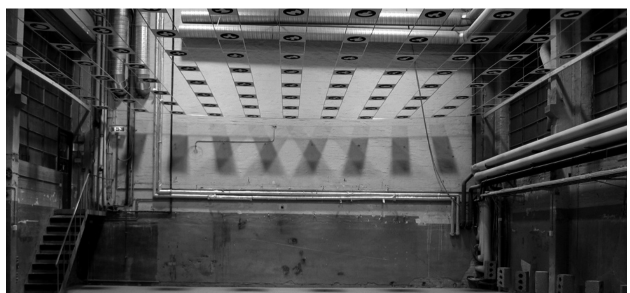

fig. 4.2.1, proof of concept 2: installation of markers.

fig. 4.2.2, proof of concept 2: visualisation of dynamic model as seen through HMD (illustration).

4.3. Proof of concept 3; Full scale, on site reconstruction.

As part of the "Forskningsdagene 2005" arranged by the Norwegian Research Council we presented a reconstruction of a medieval church, now in ruins, in its original state. The objective for this proof of concept was to investigate the possibilities and limitations when presenting a large scale Augmented Reality model on site under not controllable conditions.

The basis for the reconstruction was collected by a student at AHO as part of her course in architectural history and the result verified by the Norwegian Directorate for Cultural Heritage. A digital 3D model was made according to findings by another student and transferred to a database for use in the AR system. The positioning system was the same, but mounted after a different algorithm which ensured improved stability of the virtual model.

Users were able to approach the ruins and experience a realistic AR model of the church from different angles. Representatives from the Directorate for Cultural Heritage and the Norwegian Research Council participated in the demonstration and the event was widely covered in the national media. Just after the official event one of the researchers from IFE managed to implement the algorithms from the GPS in the AR system. It was tried and the result was of equal precision as that achieved with the graphical markers.

fig.4.3.1, proof of concept 3: the site.

fig.4.3.2, proof of concept 3: graphical markers on the ruin.

fig.4.3.3, proof of concept 3: visualisation of the church (illustration).

4.4. Conclusion from the proofs of concept.

In all three settings we based the positioning on the system with circular graphic markers. The conclusion is that even though this system has its limitations and works best indoors, it can be used for limited scale installations. Positioning based on graphical recognition is well suited for research and laboratory testing of aspects of AR, due to stability and low cost. Currently the Yoshikawa laboratory is developing a new system[8] that will open for larger distance between markers and user, thus widening the field of operation.

Participants in an Augmented Reality setup get the best experience through the use of HMD's. For a larger group of users experiencing AR simultaneously the solution can be several portable systems with HMD's or projection of a single users view to large screens.

An immediate objective for further research will be into the use of differential GPS as positioning system. For system control, IFE is currently doing research into 3D user interaction, eye-tracking and voice recognition. Real time interaction with the augmented objects is a field of investigation, as is multi-user collaboration through network with distributed databases and real-time software systems. Investigations into utilisation and visualisation of data from geographical information systems, i.e. to show hidden infrastructures, demographic information, regulatory information etc, are other planned research objectives.

5. Implications.

Planners and architects in general use digital tools and there is a move towards implementing 3D modelling of projects as common practice.

Standards are developed for 3D models as information carriers through the planning process, for presentations and assessment from the authorities on to as-built documentation and tools for maintenance. Authorities are also establishing guidelines for the use of Virtual Reality to ensure fair assessment for proposals and equality when comparing competing projects.

In contrast to VR models one only needs to make digital models of the proposed structure when using Augmented Reality, so the need for additional effort from the architects is minimal. With the introduction of AR in the practice there will therefore be no limitations due to production of content. There are no new demands on planners to expand their workload and the advantages for authorities and decision-makers should position AR as a logical continuation from VR.

In the architectural education AR will lead to new insight. The understanding of space is an essential requirement for being able to work within the field of architecture, and training in this enters into all elements of the architectural education. Today students use 3D modelling as a tool for developing their projects. With AR it will be possible for them to experience their proposals in full scale and study them as if built.

Used throughout the design process AR will let the students, as well as the practising architects, study alternatives at different levels of abstraction, thus contribute to the earlier design phases.

For architectural practice the implication will be a drastically altered way of working; complete three-dimensional models of proposed projects can be studied regarding all aspects prior to realisation.

Dynamic models and collaborative systems in AR will open to several new fields that today are restricted by limitations in technology. It will be possible to change proposed structures or model in AR and one can experience simulation of changes in physical conditions, animate and visualise pollution, noise etc. Collaborative systems give the possibility to experience full scale models on different geographical sites simultaneously.

For project-owners, politicians, decision-makers and the general public, it will be a tool that makes it possible for them to fully understand the implications of proposed plans.

Conclusion

From the research done we find that on-site Augmented Reality is functional. AR systems with on-site experience of projects, where the user can move freely in a proposed solution in full scale as if it was built, is a development of representation which can remove the problem of understanding scale and orientation in plan. They require no previous knowledge or training in representations of projects; the user will immediately see the implications of proposed projects and thus it can prove as useful tools for deciding on solutions.

Future implementation of AR in the architectural practice will have great impact on the design-process and radically improve communication of proposed projects.

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NOTES

1 Institute for Energy Technology is an independent foundation established in 1948. With a staff of about 520, IFE is an international research centre for nuclear and energy technology. The research project is done in cooperation with IFE's Visual Interface dept., Halden, Norway

2 A Survey of Augmented Reality; Ronald T. Azuma

In *Presence: Teleoperators and Virtual Environments 6*, 4 (August 1997), 355-385.

3 The International Organization for Standardization (ISO) is an international standard-setting body composed of representatives from national standards bodies and specifies worldwide industrial and commercial standards, the so-called ISO standards.

4 ISO/IEC 14772-1, the Virtual Reality Modeling Language (VRML), defines a file format that integrates 3D graphics and multimedia. VRML is a text file format where vertices and edges for 3D polygons can be specified, in addition to color, texture, transparency, animation and sound. The first version of VRML was specified in 1994 and the current version is VRML97 (ISO/IEC 14772-1:1997). VRML has now been superseded by X3D (ISO/IEC 19775-1).

5 ISO X3D, Extensible 3D, (ISO/IEC 19775-1) defines a system integrating 3D graphics and multimedia. X3D is an open-standards file format and run-time architecture to represent and communicate 3D scenes and objects, providing a system for the storage, retrieval and playback of real time content embedded in applications.

6 Graphical markers are printed black and white symbols made and positioned according to a predefined system. When used for positioning these markers are recognized by a camera and the information fed to and processed by the application.

7 Development of a Tracking Method for Augmented Reality Applied to Nuclear Plant Maintenance Work : (2) Circular Marker, Hirotake Ishii*, Hidenori Fujino* and Asgeir Droivoldsmo**
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8 Development of a Tracking Method for Augmented Reality Applied to Nuclear Plant Maintenance Work : (1) Barcode Marker, Hiroshi Shimoda, Hirotake Ishii, Masayuki. Maeshima, Toshinori Nakai, Zhiqiang Bian and Hidekazu Yoshikawa Graduate School of Energy Science, Kyoto University, JAPAN