ARchitectureView

An Augmented Reality Interface for Viewing 3D Building Information Models

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Abstract. We present a system for viewing architectural building models – specifically Building Information Modeling (BIM) models – in 3D using an Augmented Reality Tangible User Interface (TUI) and a Magic Lens interaction metaphor. ARchitectureView is meant to facilitate communication and collaboration around a shared model. We present the system overview and a number of use scenarios in which the interface would serve to improve communication across disciplines and varied technical backgrounds, while supporting a rich and coherent common understanding.

Keywords: Augmented Reality; Building Information Modeling; Magic Lens; Tangible User Interface.

Introduction

Traditional simplifications and abstractions used in design review meetings –simplified plan, section and elevation drawings, door and window schedules, etc. – are often derived from hand-drawing traditions in which scale of drawing largely controls complexity and detail of content. Building Information Modeling (BIM) aspires to displace 2D CAD data as the standard platform for project development, but BIM modeling software was created for editing. Collaborative review of design has different requirements than model editing and manipulation. To become truly compelling as a medium for carrying out complex design projects, BIM software needs to support conference-table discussion and collaborative problem solving. The standard desktop interface, while a powerful editing environment for the expert user, can be distracting for participants who must generally look away from each other to focus on a projected screen image, while the complexity is disenfranchising for the non-user. To address this problem, we have developed an Augmented Reality interface with the intent of presenting BIM data in a simple, yet compelling, fashion.

Augmented Reality (AR) is the process of viewing the real world and virtual objects simultaneously, where the virtual information is overlaid, aligned and registered with the physical world (Azuma, 1997). Often thought of as the cousin to Virtual Reality (VR), AR differs significantly from VR in one critical aspect: the retention of the physical world as a context in which virtual objects are presented and interacted with. The ideal AR system is one in which the interface theoretically disappears into the surrounding area. What is preserved in AR is the context (the real
world) in which we humans have evolved and routinely exercise our rich set of perceptual, social and communicative behaviors.

Building Information Modeling (BIM) is a system for representing and communicating information generated through the life cycle of a building. Though the origins of the term BIM are debated, the authors accept that the concept of BIM originated with Eastman’s Building Product Model (Eastman, 1976). To our knowledge, the first occurrence of the term BIM was found in (Nederveen and Tolman, 1992). For our purposes, BIM can be best characterized as data-driven modeling systems for facilitating integrated practice within the A/E/C/M domain. Additionally, BIM models are a better fit than vector-based CAD for real-time visualization and simulation.

With vector-based CAD paradigms, part-whole relationships are not explicitly determined within the model. With BIM, these data are present and can be exploited to generate more “object-oriented” interface paradigms.

Related Work
Numerous works have addressed the role of CAD in multidisciplinary design teams and most have highlighted problems with fragmentation of design and construction specialties and their use of CAD (Rosenman and Gero, 1998). The rise of BIM can be viewed as a response to the shortcomings of CAD within this domain.

The application of AR to the design and construction process is not novel. Early attempts focused on
in situ viewing of architectural and construction elements in real spaces (Webster et al, 1996). Though in situ viewing is still an interesting area of inquiry (Park and Choi, 2004), recent research has focused on the use of Tangible User Interfaces (TUIs) in AR and design. For ARchitectureView, we have adopted a TUI-based AR interface because it reduces the hardware demands of the system while still addressing the core problem: representation of building geometry quickly, efficiently, and intuitively. TUIs offer direct manipulation of real objects, which clear benefits such as reduced cognitive load and a shallow learning curve (Kato et al, 2000).

Collaborative AR interfaces are effective because the task space is embedded in the communication space. Natural communication behaviors, such as gesturing, pointing, and gazing are preserved with face-to-face AR. Experiments have shown that there are direct gains in ease and efficiency when AR is coupled with a TUI and employed for spatial tasks (Billinghurst et al, 2002; 2003). Works such as the Augmented Urban Planning Workbench at MIT (Ishii et al, 2002) have made effective use of such interfaces for roundtable discussions of large-scale urban design projects.

Though ARchitectureView employs a basic TUI, we have also introduced a minimal amount of abstraction to our interface in the form of a MagicLens (Figure 1). MagicLenses have been shown to be very effective at information filtering and semantic zooming (Bier et al, 1993). ARchitectureView’s 3D MagicLens is an extension of that developed by Julian Looser for his “Through the Looking Glass” demonstration (Looser et al, 2004). Though the 3D MagicLens is itself tangible, it represents a tool with specific affordances within the interface (described below).

**ARchitectureView System**

The intended location for the ARchitectureView system is a meeting room or a studio space wherein groups can gather around a table and freely move to different angles. Any space that can accommodate a medium-to-large physical model should accommodate the system.

**Equipment**

The user wears an eMagin 3DVisor Z800 Head-Mounted Display (Figure 2, item 1), with an eye-

![Figure 2](image)

**Figure 2**

ARchitectureView system setup and equipment.

1 - eMagin Z800 Head Mounted Display.
2 - Logitech Presenter with tracking marker.
3 - Logitech Quickcam for Notebooks Pro USB camera.
4 - Multiple fiducial tracking markers mounted on board.
level mounted Logitech Quickcam for Notebooks Pro webcam (Figure 2, item 3). The field-of-view is 40-degrees. All AR visualizations are generated with OpenSceneGraph 1.2 for the renderings and ARToolKit 2.72.1 for video-based position tracking. The combined composite image (Figure 1) is presented at between 24 and 30 frames per second (fps). The entire system is running on an Intel Core2 Duo PC, with 4 GB of RAM and an NVidia Quadro FX 4500 video card.

All ARToolKit fiducial markers are printed in black-and-white and mounted on foam core (Figure 2, item 4). Creating new markers for new buildings or component placeholders is as easy as printing a new pattern from a template and mounting it on a rigid surface. For our base-marker template, a multi-marker set was used to avoid loss of tracking due to marker occlusion by the hand or lens.

One single smaller fiducial marker is mounted at the top end of a Logitech 2.4 GHz Cordless Presenter USB device (Figure 2, item 2) to form the MagicLens. The buttons on the device are mapped to specific ARchitectureView HUD control events (listed below).

The device is easily operated with one hand and is meant to mimic the shape and feel of a magnifying lens.

System Process
The ARchitectureView system begins by loading relevant BIM data and parsing it into building sub-system layers. These layers are then polygonized and a set of default texture maps are added where absent.

![Figure 3 View of multi-user interaction.](image)
For our prototype, we used a pre-existing BIM model of Architecture Hall at the University of Washington Seattle campus. This model was constructed by a number of parties in preparation for the recently completed remodel of the building. In order to reduce the polygon complexity of the model, certain layers were manually removed. This was necessary to keep the total number of polygons under 250,000, in order to maintain the adequate frame rates necessary for real-time AR rendering. The layers retained were “Brick”, “Steel”, “Concrete”, “Interior”, and “HVAC.”

The resulting tessellated BIM model is coupled with fiducial tracking markers using ARToolKit, allowing the user to interact with digital information in a natural manner: by simply picking up a tracking marker and moving it around, the 3D building model representation comes to life.

**User Experience**

Since the user is wearing a HMD, both hands are free. Interaction with the AR representation of the BIM model is achieved in two ways: 1) by manually rotating and moving the baseboard card upon which the tracking markers are located, and 2) by the use of a hand-held MagicLens mounted to the end of a presentation remote-control.

The main representation of the BIM model is composited with a multi-marker fiducial set mounted on 28cm x 43cm piece of foamcore. The user can use one hand to rotate the baseboard marker set to gain different perspectives on the model. Multiple buildings can easily be swapped in and out or multiple base marker patterns can be employed for discrete projects.

In the other free hand, the user holds the Logitech Cordless presentation device, which serves as the MagicLens proxy. The single fiducial marker in this case represents the lens. Zooming in and out is as simple as moving the lens closer or further from the baseboard marker set. The effect is that of using a giant magnifying lens on the side of a building. This device allows the user to add and remove different architectural layers, as well as zoom, pan, and highlight layers within the scene.

A Head’s Up Display (HUD) is located in the upper-left of the visual field displaying the currently active and invisible layers (see Figure 1). The user can navigate through the HUD using thumb-buttons on the MagicLens handle.

Geometry selection is straightforward. Users can simply select and move geometric elements within the scene relative to the entire model. We have adopted a proximity based selection method as opposed to a ray-casting method. When the lens is moved through the scene, potential “selectable” building components are highlighted with a transparent bounding-box. To select and manipulate the object, the user presses a button on the lens device to select the highlighted object.

Changing transparency is also possible. Using the side button on the MagicLens, the user can increase or decrease the relative transparency of the selected layer. This feature is included in order to allow for comparison of different systems (mechanical, electrical, etc) and is analogous to using trace paper or layer overlays on a desktop CAD or BIM interface.

In addition to selecting, moving, rotating and changing transparency, the user can explode different building components. When a specific building component is selected, it can be exploded to illustrate the structure of sub-components within the object. This is a simple animated explosion without explicit semantic content, implemented by translating sub-object components away from the object centroid.

At any time during the use of ARchitectureView, a snapshot can be taken. This image is a screen-captured frame of the current first-person view which can be used as a reference at a later time or when the system is not in use.

**Discussion**

At this point in development, a number of features present in desktop-based BIM modeling and visualization are absent in ARchitectureView. The ability
to quickly generate schedules is missing; automated clash-detection is not yet implemented; 4D temporal aspects of construction sequencing are not addressed. However, there are a number of use scenarios that ARchitectureView could currently support.

**Use Scenarios**

As stated above, ARchitectureView is intended for collaborative use by individuals of varied disciplinary backgrounds. This is in keeping with the spirit of Integrated Practice growing within the A/E/C/M industry. BIM is about communication and collaboration. However, as with any collaborative endeavor, there is inevitable conflict. This is often expressed in geometry. Though a number of BIM software platforms support automated clash-detection, ARchitectureView allows for direct visual clash detection. Because multiple constituencies can bring models or component subsystems to the table – and these can be easily superimposed and composited – such clashes visually jump out at the group. Beyond just detection of pathology or conflict, we believe this system would engage a larger user-base with varied levels of technical expertise, lowering the bar for active engagement with the virtual model.

ARchitectureView currently supports a rich set of isolation and transparency interactions with layers and components within layers. We predict that this would improve communication during meetings within a design team. The ethos is “show, don’t tell.” Because issues would be actively illustrated and options explored, it is likely that the process would drastically improve upon the standard pin-up or projected-slide style of presentation.

ARchitectureView would also be well suited to client presentations. Due to the novelty and intuitive nature of the interface, passing the virtual model to the client is as easy as handing a sheet of paper across a table. Little if any instruction is necessary for basic viewing tasks. A small amount of instruction is needed – which of the 6 buttons perform which operations – to perform relatively complex tasks quickly. This should be compared to the time necessary to learning the menu system of a desktop-based GUI.

**Future Work**

Addressing the issue of model complexity is crucial. With continued development, it would be important to pursue ways of automating the importation of the BIM models, so as to not sacrifice certain systems (electrical, etc.) with extreme geometric complexity (or finding appropriate geometrical abstractions and presentations of such systems). Additionally, this interface should be evaluated against “traditional interfaces,” such as computer desktop viewing and printed documents, to determine whether it allows for detection of geometric clashes and assessment of aesthetic and operational issues. A set of tasks could be developed for two-user face-to-face collaboration around the shared model. A time/error based efficiency measure should be employed along with a protocol analysis of observed behavior (first-person views will be captured) as well as a subjective post-study participant questionnaire.

**Conclusions**

We have presented ARchitectureView, a system for intuitive and collaborative viewing of BIM models in 3D. We have used a Tangible User Interface metaphor and a MagicLens for interaction with the various building components. We have sketched a number of use scenarios in which ARchitectureView may prove beneficial and addressed the limitations of the current instantiation. Though in an early phase of development, ARchitectureView demonstrates the presentation of complex BIM data in a simple and intuitive fashion, using an interface with a shallow learning curve.

**Acknowledgements**

The authors would like to thank the members of the Design Machine Group in the College of Architecture and Urban Planning at the University of Washington:
Professor Mehlika Inanici, Kat Cheney, Chih-Pin Hsiao, and Randolph Fritz. Thanks to Jerry Laiserin for sharing his history and perspective on BIM and its origins. Thanks also to ARToolworks, Inc. and the HIT Lab NZ for its generous support in allowing our project access to advanced versions of osgART and ARToolKit.

References


