Mobile Augmented Reality for Building and Construction

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ABSTRACT

We describe a software architecture for providing mobile user at the construction site with two-way real-time augmented reality access to 4D CAD and BIM information. The system allows the user to compare scheduled building information models with the situation at the construction site in real time, as well as to attach position and time aligned visual and other feedback to the building models at the office.

1 INTRODUCTION

Building and construction is widely recognized as one of the most promising application fields for Augmented Reality [1, 2]. Recent developments in mobile processing units, camera quality, different sensors, wireless infrastructure and tracking technology enable AR applications to be implemented even in demanding mobile environments [3]. Building Information Models (BIM) are another main technology driver increasingly used for data sharing and communication purposes in real estate and construction sector [4]. Combined with Augmented Reality, 4D BIMs could facilitate comparisons of the actual situation at the construction site with the building's planned appearance at the given moment. Such mobile augmented information available at the construction site would have various applications for construction work planning, verification, training and safety, as well as for communication and marketing prior to construction work.

The related camera tracking technologies open up further application scenarios, enabling us to implement mobile location based visual feedback from the construction site to the CAD and BIM systems. We may think of adding elements of reality e.g. images, reports and other comments to the virtual 4D model, with full awareness of the user's location in time and space. Altogether, the tracking and interaction techniques can thus be made to serve the complete spectrum of Mixed Reality [5], forming a seamless interaction cycle between the real world (augmented with virtual 3D/4D model data) and digital building information (augmented with real world data): see Figure 1.

The AR4BC project (Augmented Reality for Building and Construction) between VTT and industrial partners from the Finnish B&C sector aims to providing the mobile user at the construction site with direct two-way access to 3D CAD and 4D BIM information. Our article describes the overall AR4BC software architecture, from content creation (4DStudio) and positioning tools (MapStudio) through onsite visualisation (OnSitePlayer) and wireless data sharing (OnSiteServer) up to mobile interaction and visualisation (OnSiteClient). Special emphasis is on authoring tools, i.e. managing different model formats, linking them to 4D information, placing the models in geo coordinates, as well as managing complex data intensive building model information on thin mobile clients. We also discuss model based tracking and other methods to match the camera view with the virtual model description of the building and its environment, visualisation and interaction tools, as well as the feedback mechanisms to be enabled.

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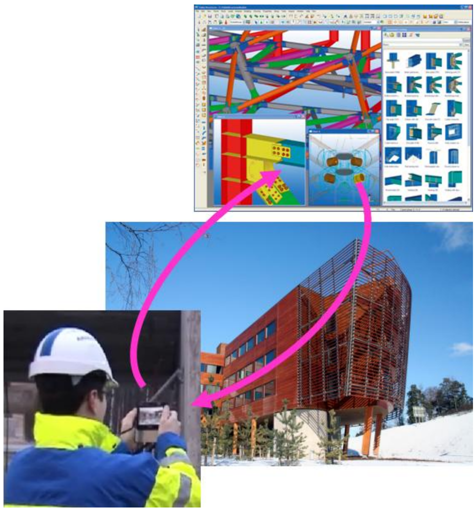

Figure 1. Mixed reality interaction cycle: mobile view of construction site augmented with BIM (arrow down), and feedback from mobile device back to BIM (arrow up).

2 SYSTEM OVERVIEW

2.1 Hardware

The onsite visualisation systems (OnSitePlayer and OnSiteClient extension) are developed with a lightweight UMPC (Ultra Mobile PC) such as the Sony Vaio UX in mind. However, stand-alone operation of the full functionality (OnSitePlayer) with complex BIMs typically requires a high-end laptop including good 3D display hardware. The GPS positioning information is received from the external GPS module via Bluetooth connection. Basically any GPS module with Bluetooth connection supporting virtual serial port communication can be used. For sensor based tracking we are currently using OS5000-US Kit 3 axis Digital Compass from OceanServer Technology Inc.

2.2 Software Modules

The prototype system is divided in three parts; 4DStudio, MapStudio and OnSitePlayer (see Figure 2). The Studio applications are in an authoring role of the system while the Player provides a rich augmented reality view and mobile feedback interface at the construction site. OnSitePlayer can be operated either as a stand-alone, if there is enough processing power and memory on the mobile device, or as a client-server solution distributing the heavy computation to the server, and interaction and display to the client.

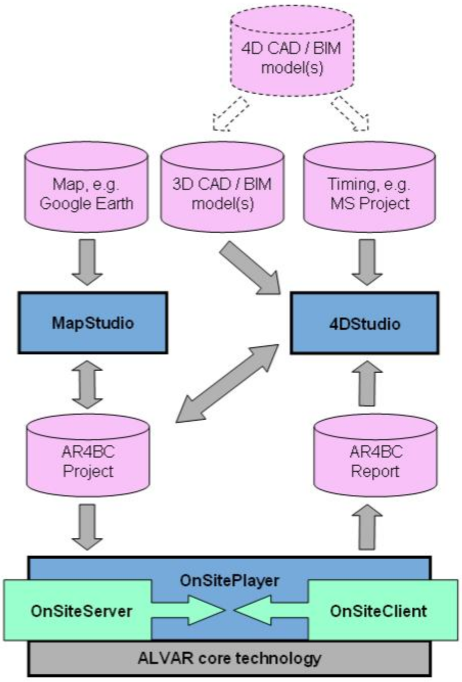

Figure 2. System overview

For rendering we use OpenSceneGraph 2.8.0 and the GUI is built using the wxWidgets 2.8.9.. The applications can handle all OSG supported file formats via OSG's plug-in interface (e.g., OSG's internal format, 3DS, VRML) as well as IFC, using the parser module developed by VTT.

The 4DStudio software is responsible for handling and modifying the 4th dimension i.e. the timing information of the BIM. It allows the user to define the construction timing related values part by part. The visualisation of the workflow in certain time range is another central feature.

The 4DStudio software also provides a user interface to browse and visualize incoming reports from the construction site, created by the user with the OnSitePlayer. The feedback reports are used to document various notes, verifications and problems detected on site. Typically, they contain text descriptions of the issue, perhaps photographs, time stamps, and position information. All these pieces of information are assembled into a single XML file, which is kept separate from the original model files, but can be viewed together with the model using 4Dstudio.

The MapStudio software is used to map the BIMs in geo coordinates (GPS+orientation). Now we don't insert the building model into Google Earth like we did in our previous implementation [6], instead we capture the Google Earth geo information into our application. Other map data bases could be used as well. The MapStudio can also be used to add some additional models around the construction site, so called block models. The block models can be used to mask the main construction model, or to add visual information of the surroundings.

OnSitePlayer is the main augmented reality visualisation, interaction and feedback software on the construction site. OnSitePlayer is able to visualize the models in right position (location, orientation and perspective) by utilizing the model's GPS coordinates in combination with the user's position. User positioning can be done automatically using GPS, or manually defined on the site.

Virtual models of the construction sites can be very complex and consequently mobile devices used for onsite visualisation may not be capable of smooth real time augmentation. To overcome this problem we employ the client-server architecture. The OnSiteClient software is used on the construction site for tracking and for visualizing a 2D image of the model, i.e. the 3D model projected to the client's viewing coordinates. The viewing projection is provided by the server software OnSiteServer and it needs to be updated only once in a while (not real time). Both the OnSiteClient and OnSiteServer modules are obtained as extensions of the stand-alone OnSitePlayer software with relatively small modifications.

Finally, shown at bottom of Figure 2, the tracking algorithms are implemented in our augmented reality subroutine library ALVAR (A Library for Virtual and Augmented Reality) [8]. It provides generic solutions for marker and markerless vision based tracking, as well as for hybrid solutions using electronic sensors.

3 Conclusions

At this point the system is on prototype level and we have focused mainly on authoring and interaction aspects. However, the current system already exceeds by far the functionality of our earlier implementation [6]: being able to deal with scheduled 4D BIMs; support of general OSG compatible file formats as well as IFC; new interactive tools for object placement in geo coordinates; integration of compass for orientation tracking; completely re-designed user interface with selectable 2D and 3D views; and mobile feedback to the office systems.

Further implementation details are provided in [7], including: integration into existing tools and data; communication between the software modules; linking the time schedules to the BIMs, interaction and visualization of with 4D BIMs; feedback mechanisms (reports); model placement in geo coordinates; mobile user interface and interaction; notes on tracking methods (combining model-based, feature based and sensor-based); client-server implementation; optimizations for mobility; and notes for rendering of augmented building models.

References

[1] G. Klinker, D. Stricker, D. Reiners. Augmented reality for exterior construction applications, in *Augmented Reality and Wearable Computers*, Barfield W. and Claudell T. (eds.), Lawrence Elrbaum Press 2001.

[2] C. Woodward, J. Lahti, J. Rönkkö, P. Honkamaa, M. Hakkarainen, J. Jäppinen., K. Rainio, S. Siltanen, J. Hyväkkä. Virtual and augmented reality in the Digitalo building project, *International Journal of Design Sciences and Technology*, Vol 14, No 1, Jan 2007, pp. 23-40.

[3] J. L. Izkara, J. Perez, X. Basogain, D. Borro. Mobile augmented reality, an advanced tool for the construction sector, *Proc. 24th CIB W78 Conference*, Maribor, Slovakia, June 2007, pp. 453-460.

[4] B. Koo, and M. Fischer. Feasibility study of 4D CAD in commercial construction, *Journal of Construction Engineering and Management*, Vol. 126, No. 4, July/August 2000, pp. 251-260.

[5] P. Milgram and F. Kishino. A Taxonomy of Mixed Reality Visual Displays, *IEICE Transactions on Information Systems*, Vol E77-D, No 12, December 1994.

[6] P. Honkamaa, S. Siltanen, J. Jäppinen, C. Woodward, O. Korkalo. Interactive outdoor mobile augmentation using markerless tracking and GPS, *Proc. Virtual Reality International Conference (VRIC)*, Laval, France, April 2007, pp. 285-288.

[7] M. Hakkarainen, C. Woodward, K. Rainio. Software Architecture for Mobile Mixed Reality and 4D BIM Interaction, *Proc. 25th CIB W78 Conference*, Istanbul, Turkey, Oct 2009, 8 pp.

[8] ALVAR home page www.vtt.fi/multimedia/alvar.html