Augmented Reality-Based Education and Fire Protection for Traditional Korean Buildings

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ABSTRACT

This study examines an application of Augmented Reality technology (AR) for Korean Cultural Traditional Buildings, specifically, the Namdaemun Gate, "National Treasure No 1" of the Republic of Korea. Unfortunately, in February 2008, the Namdaemun Gate burned down, despite the efforts of many firemen, as the main difficulty was getting the fire under control without any structural knowledge of the wooden building. Hence, with the great advances in digital technology, an application of virtual technical information to traditional buildings is needed, and the new technology of AR offers many such advantages for digital architectural design and construction fields. While AR is already being considered as new design approach for architecture, outdoor AR is another practical application that can take advantage of new wearable computer equipment (Head-mounted display also know as HMD, position and orientation sensors, and mobile computing) to superimpose virtual graphics of traditional buildings (in this case, Namdaemun Gate) in a real outdoor scene. Plus, outdoor AR also allows the user to move freely around and inside a 3D virtual construction, thereby offering important training opportunities, for example, specific structural information in the case of firemen and mission planning in the case of a real-life emergency. In this example, the proposed outdoor AR system is expected to provide important educational information on traditional wooden building for architects, archaeologists, and engineers, while also assisting firemen to protect such special buildings.

1. Introduction

The Namdaemun Gate is one of the most famous wooden structures in the Republic of Korea. Its construction began in 1395 during the fourth year of the reign of King Taejo from the Joseon Dynasty, and was completed in 1398. Over the next six centuries, the Gate underwent several renovations with the last major repairs conducted in 1962, when the Korean government designated it as "National Treasure No.1".

Unfortunately, on February 10, 2008, the Gate was completely destroyed by fire, despite the efforts of over 360 firefighters. Due to the complex hermetic structure of the Gate, the jets of water were unable to reach the center of the fire, making the rescue attempts useless. However, if the firefighters had been able to see a virtual model of the traditional building, it could have provided valuable information for more effective rescue strategies. In fact, various graphic technologies already exist that could provide such support.

Extensive research has already been conducted on the application of CAD to Historical and Cultural buildings, for example, 3D Laser Scans, GIS, and VR. Plus, 3D graphic applications have played an important role in the design and restoration of several heritage projects. Among such applications, Augmented Reality is a new technology that enables the interaction of 3D computer graphics in a real world context real-time. As such, the user is not limited to viewing the real world augmented with virtual objects generated by computer graphic software, but can also interact with those virtual objects in real-time. One example of the application of AR to Cultural Heritage projects is the Archeoguide [1] that allows the user to see the completely re-generated virtual temple of Hera in Greece superimposed over the surviving ruins and the ARQuake game [2],[3] is another example of using outdoor AR paradigms to provide a re-generated game scenario based on a real environment. Yet, these projects focus on the viewing process through only Head Mounted Display (HMD) and are just intended for tourism or entertainment purposes. Accordingly, this study examines the use of AR technology as a new tool for protecting and maintaining traditional buildings, including emergency situations. Thus, the Namdaemun Gate was selected as a case study and "built up" using an outdoor AR technique with a mobile AR system. The prototype AR system also performs another implementation manner beside current outdoor AR systems, gathers flexible functions and technical information supporting capabilities. A wearable PC device set is also proposed for use in emergency situations.

2. Overview of augmented reality technology

Augmented Reality (AR) is a new technology that involves the overlay of computer graphics on the real world. As a result, the user can see the real world augmented with virtual objects, and can also interact with these virtual objects. AR is also grouped under the umbrella term Mixed Reality

(MR), which refers to a multi-axis spectrum of areas that cover Virtual Reality (VR), Augmented Reality (AR), telepresence, and other related technology (Figure 1).

Augmented Reality systems combine digital information and the real world in a way that the user experiences them as one. A particular important property of AR is locating virtual objects in the right place and position, which makes the Tracking System one of the most important components of an AR system. Essentially, an AR system must be able to follow the user's point of view dynamically and keep virtual objects aligned with real world objects. The basic components of an AR system are a display, camera, and computer with application software, plus various different kinds of hardware can be used, for example, camera phones, PDAs, lap-tops, HMDs, and wearable computer systems.

Although Augmented Reality has only been studied for one decade, the growth and progress in the past few years have been remarkable. As such, AR technology has many possible applications across a wide range of fields, including entertainment, education, medicine, military training, engineering, and manufacturing [5].

◄ Figure 2. AR application in entertainment and medical fields.

◄ Figure 3. AR application in military and civil engineering fields.

It is also expected that other potential areas for application are still to appear with the dissemination of this technology. During the early stages, the main focus of AR development was related to hardware technology rather than usability. However, the rapid development of mobile devices (handheld) with better processing capacities and long-lasting batteries has increased the potential of lightweight mobile AR systems. Thus, mobile AR devices are now one of the most promising emerging technologies for developing AR in an outdoor environment. Therefore, this study presents an outdoor AR system housed in a backpack for use by firefighters. It utilizes a wireless network environment and GPS localization.

2.1. Outdoor augmented reality and technical challenges

Although many AR systems have been developed in recent years, the majority of systems are intended for small indoor environments, where the conditions are easier to control (e.g. brightness variation, occlusion, 3D registration). However, outdoor AR is also an important application area for AR technology, where virtual graphics are superimposed on an outdoor scene. In particular, outdoor AR requires the virtual graphics process that generates the overlay to withstand many unstable effects from environmental elements in real-time, while also allowing the user to move freely around the real site for observation.

Despite this, recent advances in computer vision and mobile computing can now facilitate the development of more complex AR applications for outdoor environments, where working conditions are hard to control (sunlight, unrestricted mobility, etc.) and where different types of tracking sensors (GPS sensor, compass sensor) can be used. Notwithstanding these developments, outdoor AR still presents several problems that are the subject of intense research, including 3D localization, visualization, interaction on mobile devices, and the use of geo-referenced data. Thus, the development of an outdoor AR system presents real challenges in terms of technology, methodology, and industry [6].

The technological issues related to outdoor AR mainly involve the development of new techniques in the fields of localization, 3D visualization, and interaction on handheld devices. The mobility of the user in an unrestricted and unprepared environment makes the localization process difficult. Usually, outdoor AR techniques combine an absolute location and relative location to provide continuous user localization. Absolute location involves estimating the user's position using for example GPS, whereas relative location uses the motion of a sensor, like an accelerometer or gyroscope, to estimate a relative displacement of the user with regard to a reference position. 3D models of the environment are typically used to initialize the localization procedure. However, the problem of accurate localization in a natural environment and 3D registration (unknown surrounding, multiple sources of information, risk of occultation) is still an active field of research.

In addition, outdoor AR applications need a realistic 3D virtual representation of the real environment. While 3D models are very useful for pose estimation from 2D/3D matching, the construction of simple and rich 3D models remains a major challenge for AR.

The information available to user on site is normally huge. However, to display such data in real-time on a display device with limited processing power and low storage space is another problem that arises in the case of mobile AR. Thus, the recent development of a wearable PC is of particular value to the development of outdoor AR and will be examined in this study.

2.2. Application of outdoor augmented reality

The field of cultural heritage involves the restoration or re-generation of many traditional buildings at the original sites based on surviving ruins. Restoring a virtual model of traditional building in an outdoor environment provides 3D graphics to architects or archeologists, so that they can see beforehand what problems of building (or restoring) work in near future are required. One good example of the application of outdoor AR for Cultural Heritage is the Archeoguide project that provides visitors with a simulated view of ancient Greece when they are at the actual historical site (Figure 4).

◄ Figure 4. Outdoor AR view of Hera temple in ancient Olympia, Greece [1].

However, the present study examines the use of outdoor AR to create a 3D model for the purpose of re-simulating a 3D model of Korean traditional building at a real historical site in outdoor environment. In addition, it is also intended that this application of outdoor AR can be used to provide practical training information for firemen, for example, on the structure of traditional wooden buildings, and since AR technology can provide user interaction in real-time, it is also hoped that the proposed AR system will be able to help guide firemen in the case of real emergencies.

However, the real valuable advance of this study is the prototype AR system that allows the user to interact with a virtual building with more flexibility and with capacity to view the full supporting technical information of the building. Especially important, the user can move freely around while

observing the building from many directions. Further, the AR system can support an AR aviation view. The study produced several results, which will be presented in the following sections of this paper.

3. AR used for education and fire protection

3.1. GPS and compass-based position & orientation tracking

To integrate virtual objects into a real environment, a tracking system is needed to determine the user's exact position and direction of view. However, despite the availability of many tracking technologies that offer position and orientation tracking with high precision and low latency, none of these systems are suitable for outdoor usage with the precision required by the present application. Thus, integrating different tracking technologies into one hybrid system would seem to be the most promising method.

First, a rough positioning of the user is achieved by using GPS and a compass system [7], while the exact tracking system is based on vision-based tracking (reference images based tracking).

The only additional hardware needed to perform the vision-based tracking is a small off-the-shelf camera attached to the user's Head-Mounted Display (HMD) and a frame grabber integrated in the Mobile Unit. As such, the tracking system determines the user's viewpoint based solely on video images. The system is developed based on the idea of image registration, which is a global method that takes into account the whole image of the user's field of view.

The method assumes that a large number of calibrated images are stored in a database, indexed according to the spatial coordinates from which they were taken. The method then computes a comparison between the current user image (taken from the camera) and a number of site images in the database whose indexes are close to the coordinates provided by the GPS and compass devices. The matching is done by considering the image as a whole (global method), instead of identifying landmarks in each image (local method). When the area of the two images being compared overlap by approximately 40% or more, the method can correctly compute the warping transformation of one image to the other. This transformation is then used to provide accurate head-pose estimation, as the coordinates of the database image are already known. In fact, in the case when there are pre-rendered images of 3D reconstructions of traditional buildings rendered from the same point of view as the stored site images, the same warping transformation can be used to transform (fast and accurately) the pre-rendered image and then display it on the user's HMD, thus achieving 3D visualization as well.

Results for this approach have already been measured when tracking at a speed of 10 frames per second on a low-end desktop PC, and several optimizations are being developed to increase this speed to 20-30 frames per second. Therefore, this approach would seem to hold the best promise

for accurate head-pose estimation in wide outdoors areas. In contrast to landmark recognition-based methods, which can fail to track due to occlusions of the landmarks from the user's point of view (due to other objects, such as humans and animals, obstructing the user's field of view), this image registration-based tracking method is far more robust, as it is a global method requiring any overlap in the image of only 30-40%.

The GPS information helps in the case of calibration and recalibration. Plus, the GPS and compass information aid in predicting the user's path and which direction they will approach in order to prepare which data to use next.

Therefore, the proposed method avoids the necessity of an accurate 3D model database and makes use of an image-based rendering technique.

3.2. System structure

As the Mobile Unit (MU) needs to be easily carried by the user on site, it must be small, lightweight, and easy to handle, even for unskilled users. Thus, it has to be an intuitive wearable or portable device. Furthermore, since the current case study is for use by firemen, the system must also be robust enough to withstand severe outdoor conditions and be cost effective.

The connection is also another important issue, as many peripheral devices need to be attached to the main module. First of all, a display unit, such as a Head-Mounted Display (HMD) or portable liquid-crystal display (LCD), with a reasonable resolution is required. These devices are used to present the augmented images of the reconstructions as well as the system's user-interface. In order to interact with this system, a mobile input-device has to be provided. A touch-screen integrates best with a portable LCD solution, yet the use of an HMD glass requires an extra device to make it easy to use in an outdoor environment.
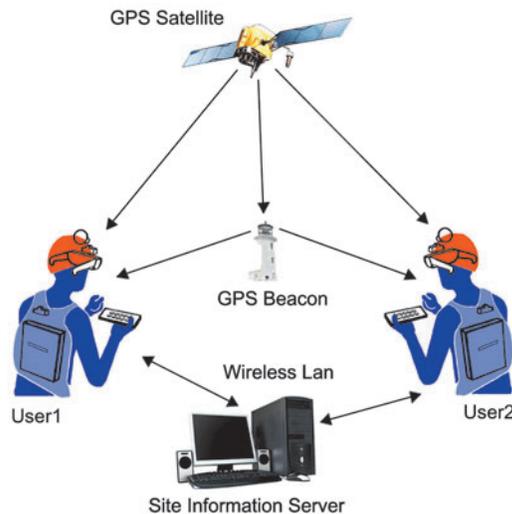
◀ Figure 5. Proposed system architecture.

Figure 6. Mobile Unit system diagram.
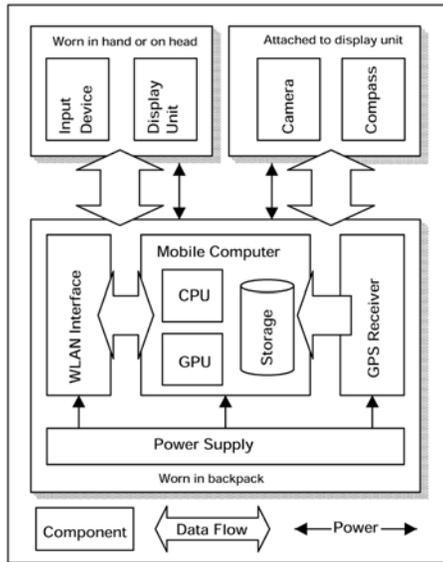
In outdoor AR, the user position is determined using a Global Positioning System (GPS) and the user orientation primarily based on information from an electronic compass. The position and orientation tracking is facilitated by a web camera and an electronic compass both mounted on the HMD, capturing and measuring the user's current field of view. Furthermore, a GPS receiver determines the mobile user's position on-site delivering rough initial estimates to the tracking software.

The initial prototype system is self-contained, where all the data presented to the user is store locally on the mobile unit, so a Wireless Local Area Network (WLAN) interface is required. This also allows communication with other mobile units (other participants) in the same area. The WLAN is used to synchronize certain presentations for the user group with a centralized site-server distributing updated datasets and keeping track of individual units on-site.

In summary, the hardware components of the system include a Site Information Server, Mobile Unit, and WLAN.

### 3.3. Wearable PC devices (Mobile Unit)

The proposed outdoor AR system prototype basically consists of two main components working in parallel. In addition to the software part of the system, several supporting hardware devices are used to provide input and output data, including a GPS receiver, orientation tracker (electronic compass), and Head Mounted Display (HMD). The miniature keyboard (Phoenix forearm- mounted keyboard) also is used for manual entry data.

Clearly, the main module of the mobile device set needs to provide suitable interfaces for all the peripheral devices and also drive them. Thus, for the case of outdoor working in real-time, special care must be taken

regarding the power consumption of the various components, as well as the power supply included in the mobile device set. Figure 7 presents the wearable computer prototype (in a backpack), and Figure 8 shows how the device set is used in the case of firemen.
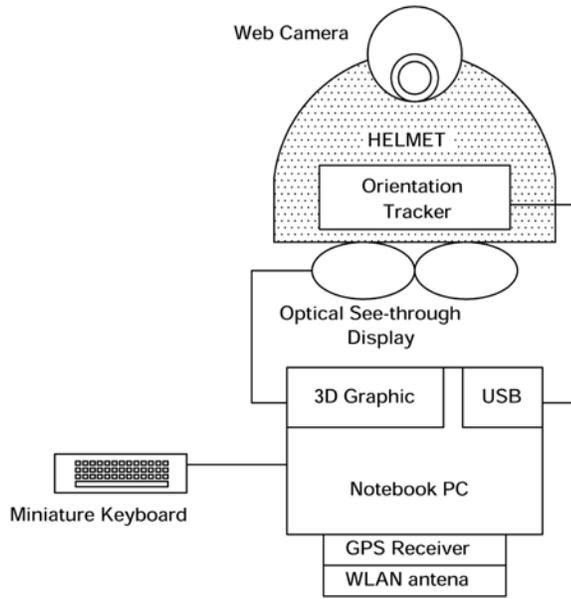
◄ Figure 7. Wearable PC model.
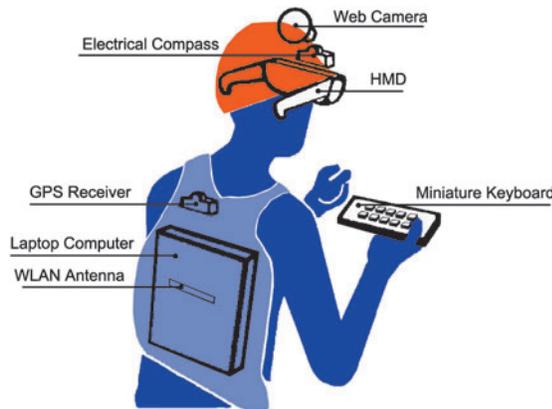
◄ Figure 8: Mobile unit device (equipped for ordinary AR user or fireman).

GPS receiver and orientation tracker

A Garmin eTrex HCX GPS receiver together with an InterSence Intertrax2 head tracking system were used for the first prototype. Although the accuracy level obtained from the GPS used in the prototype phase was around 3 meters, the user's position and orientation collected in this phase could still be used in the next phase by performing a one-time calibration

► Figure 9: Garmin eTrex HCX GPS receiver and InterSence Intertrax2 fixed on Optical See-through Display (i-Glasses-Scape II HMD).

just after the AR software starts capturing live scenes. However, in future, a more accurate GPS system that can easily be adapted for use with the AR software would lead to more practical results.

Head mounted display (HMD) and camera

The HMD mainly consists of two parts: a video input device and see-through display. Almost any kind of video input device can be used as the live video stream capture device (i.e. webcam or camcorder).

Yet, since the main aim of this study is to provide an AR scene for firemen working under severe conditions, the system needs to leave the hands free. Therefore, an I-Glasses Model I-Scape II is used to superimpose virtual objects on the real scene. While the user can still see the real life scene, the virtual graphics are overlaid on transparent glass. Figure 10 shows an example of how the components of the Augmented Reality system work together to produce the final result on an optical see-through display.

The determination of the user's exact position and orientation parameters, so-called pose, is based on a video tracking algorithm that analyzes the user's current view of special features, which is why the camera has to be attached to the display unit, permanently capturing the field-of-view and transferring the image sequence to the Mobile Unit's main module.

► Figure 10. Schematic illustration of optical overlay-based Augmented Reality.
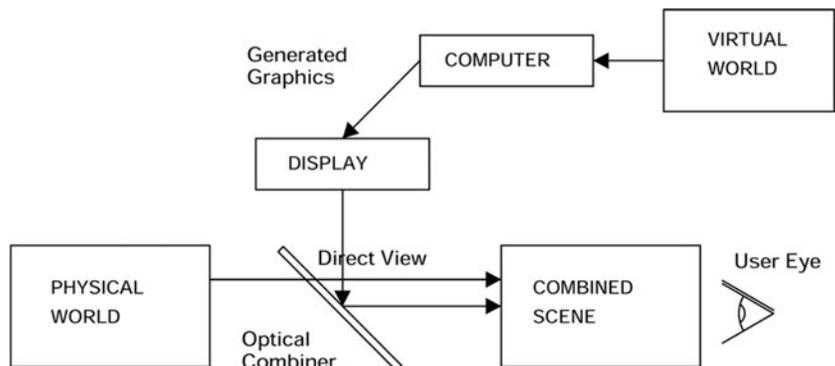
The more images the system can process, the more accurate the pose that can be extracted. Consequently, there are two primary requirements for a suitable camera: the image quality and the maximum frame-rate it is able to capture. In the present study, a Logitech Quickcam Vision Pro webcam (which can support a resolution of 1600x1200 pixels) is used as the video input device.

Portable PC

For the user to be able to move freely around in the real world, the system should be placed in a manner that can be easily carried and accessed anywhere. Thus, a Compaq HP V3000 laptop with a 2Ghz CPU speed and 2GB memory is used. Finding an optimum balance between the processing power and the battery life on one hand and portability on the other hand is always an important issue in this step for almost any outdoor AR application. For the more powerful the computer system, the heavier it is to carry around.

3.4. Software

Due to the advantages of a modular platform over an integrated platform, the main goal is to keep the software as modular as possible. Thus, the final result is a series of independent interconnected modules that can be simply replaced or updated when needed. The current AR software is a platform on which four different modules act simultaneously and produce a unique output that can be seen through the HMD.

The first module is a unit that captures the live video stream from the real environment using the video input device. The second module is mainly a data collector from the GPS receiver that provides the software with the user's global position in terms of the longitude, latitude, and altitude. The third module is a data collector from the orientation tracker which basically gives out three head rotation angles around each axis in real simulation time. The fourth module is essentially a graphical module which reads the data from the linked files and places each virtual model in the user's view on a real-time basis. Using these modules and knowing that the location and orientation of objects must be kept independent of the user's position and orientation, for any transformation of the user, a reverse transformation is calculated and applied to the objects in the user's view so that the graphics always appear fixed to a particular location.

Having a modular platform makes it possible to choose between a wide variety of input and output devices and resources and still obtain satisfactory results from the AR software. For example, data for virtual objects can be input to the software using the format of CAD models (3DS, VRML, etc). In any case, the software is capable of collecting usable data, such as dimensions and global coordinates, for any virtual object presented in the data file and inputting them to the corresponding modules for further

procedures, such as translation and rotation. At the same time, the user's position and orientation are obtained from the GPS receiver and orientation tracker connected to a part of the user's body, and using this data, the AR software can then develop a perspective viewing frustum visible through the HMD. As the user moves around, user movements are detected and a relative transformation matrix is calculated and updated.

Applying the inverse of this transformation matrix to the virtual objects in the viewing frustum, the AR software tries to keep them in a fixed position so that they are not affected by the user's movement. To give an example, a virtual object that is visible with a specific combination of the user's position and orientation should not be visible when the user turns 180 degrees around. To do so, a -180 degree rotation should be applied to the object so that it becomes outside the user's view. Meanwhile, some new objects may become visible after applying a -180 rotation matrix to the original coordinates. Figure 11 illustrates the schematic flowchart used by the software when reading virtual object data from a CAD file.

► Figure 11. Basic steps taken by AR software when reading virtual object data from file.
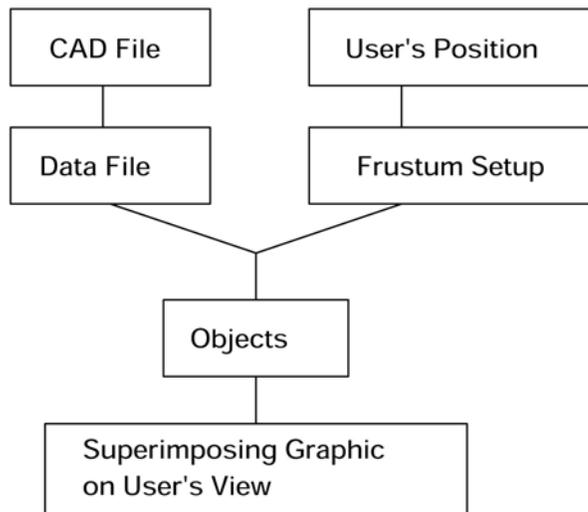
4. Implementation

4.1. Scenario

This system was tested in an outside environment within the context of visiting a virtual model of Namdaemun Gate to obtain technical information about it. The user wore a wearable computer device and started the experiment with a wireless network interface (WLAN) running from the Site Information Server. At the real site, a life-size virtual Namdaemun Gate was overlaid and the user was able to walk around and view it. When the user turned their head in a different direction, the transformation data from the electrical compass on the helmet helped the

system to provide a suitably rotated angle of the virtual object. Actually, the AR user was able to walk inside the virtual traditional building and the outdoor AR system provided full coverage of interior space. The user clicked a button on a miniature keyboard (Phoenix forearm-mounted keyboard) when he or she wished to see more technical information on the virtual Namdaemun Gate.

In this case, some results for extra technical information are presented. For example, the outline graphics of the columns set or technical notations of the timbered components or main wooden framework can be enhanced to superimpose on the virtual building graphic. Upon choosing any option, a correlative virtual element can be drawn on the head display and superimposed on the actual scene. Furthermore, based on the HMD's headphones, the user can also retrieve annotations or vocal instructions directly from another person participating in the same activity.

Therefore, the above results demonstrated the suitability of the prototype system for the purposes of cultural architectural education and practical training. The outdoor AR system also allows firemen to train following a real script, work together in the same outdoor AR system, and obtain additional information in real-time.

4.2. Operation for fire protection training

In a fire control context, one of the big issues is that firemen must approach and dismantle a dozen complex wooden components that are unknown to them. For instance, in an obvious emergency situation, firefighter teams attending Namdeamun for the first time are given a mission to approach a predefined point of the fire. To do so, they must dismantle a dozen components according to the system guide simultaneously. In order to discuss the procedure before the firefighting operation, the prototype outdoor AR system can direct firemen teams to realize component shapes before they even visit the site. And then onsite, the wearable AR device set can assist firemen to identify required wooden components as they approach the building.

However, in the case of fire protection training for extensive complex traditional buildings (e.g. palaces or mausoleums), assisting firemen teams to approach, access and move across the buildings in different ways is of critical importance. This enables firemen teams to carry out a much more cohesive and informed collaborative operation. Thus, instead of executing repeated firefighter training at a valuable if complex traditional building, the prototype AR outdoor promises to create complex virtual buildings that appear to be life-size on real site. It is designed to be robust and informative even after repetitive training sessions. Here, several participants equipped with Mobile Unit (wearable devices) would find it easy to approach and observe a range of complex components of a building. For training to produce good results, the outdoor AR system also can support AR aviation view (Figure 12-*Left*) in

order for team leaders to observe the overall rescue operation, so that they can propose suitable commands for firemen teams for specific situations. The proposed AR system is also expected to be of value in the case of real emergencies. However, further improvements in AR hardware are still needed in order to withstand severe conditions.

4.3. Test results

The following describes the system operation. In this experiment, although the actual location of the Namdaemun Gate was not used, the main purpose was to demonstrate life-size 3D virtual graphics of Namdaemun Gate in an outdoor environment. All the participants were able to see views of the virtual Namdaemun Gate matching their respective locations. In this hypothetical example, they can be firemen who need to carry out practical courses in extinguishing fire. The group discussion for planning execution of the mission is facilitated through this outdoor AR system. When required, the particular components of the building were added (main column set, bracket set, roof beam, timbered specifications, etc.), providing the user with specific architectural information. The result showed this prototype would prove worthwhile for training firemen to successfully extinguish fires. Nonetheless, the robustness and weight of the Mobile Unit are still important problems that need to be addressed in further studies.

► Figure12. Left: Namdaemun in AR aviation view. Right: A life-size 3D model overlaid on the real gate.

► Figure 13. Left: Users carried a wearable PC and roamed freely around and into the virtual building. Right: The technical notices were turned on by clicking button commands on a miniature keyboard.

5. Conclusion

This study proved the feasibility and potential of using a mobile outdoor Augmented Reality system for disaster prevention or restoration, as well as a tourist guide of traditional buildings, and for educational purposes in a real outdoor environment.

In this study, the wooden framework architecture of Namedaemun Gate was reviewed as a new application of Augmented Reality for Korean Historical Buildings. As such, the components were presented based on a 3D model of the wooden framework, including the animated joints and joining of the component groups to illustrate the framework construction interactively in a real-time simulation.

AR technology opens up new research fields, especially in engineering and architecture. In an outdoor AR environment, the architecture exploration process becomes more convenient and more intuitive, as the architecture work and relative operations can be investigated and manipulated at the same time.

Furthermore, outdoor AR can also be an animated simulation tool of historical buildings at real sites, allowing the user to view restored buildings through an HMD, video display, or PDA. Thus, the potential uses of outdoor AR are expected to increase, especially for architecture education and disaster prevention in the case of Korean traditional buildings. However, our research would be continued in future works, which are focused on improvements of functional operations and for enhanced AR hardware usability especially for firefighting work.

Acknowledgements

References

1. http://www.cultivate-int.org/issue9/archeoguide/index.html [2-2009].

2. Pierkarski, W., Gunther, B. and Thomas, B., Integrating Virtual and Augmented Realities in an Outdoor Application, *Proceedings of the 2nd IWAR*, IEEE, Washington DC, 1999, 45-54.

3. Thomas, B., Close, B. et al, ARQuake: An Outdoor/Indoor Augmented Reality first person application, *Proceedings of the 4th International Symposium on Wearable Computer*, IEEE, Atlanta, GA, 2000,139-146.

4. Milgram, P., Takemura, H., Utsumi, A., and Kishimo, F., Augmented Reality: A class of displays on the real-virtuality continuum, in: Das, H., ed., *Proceedings of the Telemanipulator and Telepresence technologies*, SPIE, Bellingham, Wash, 1994, Vol.2351, 282-294.

5. Zalatanova, S., Augmented Reality Technology, *GISt No17*, Section GIS technology, TU Delft, Netherland, 2002.

6. Azuma, R., The challenge of Making Augmented Reality Work Outdoors, in: Ohta, Y. and Tamura, H., eds., *Mixed Reality: Merging Real and Virtual World*, Springer-Verlag, Japan, 1999, 379-390.

7. Stricker, D., Kettenbach, T., Real-time and Markerless Vision-based Tracking for Outdoor Augmented Reality Applications, in: Ronald, A., Klinker, G., Tamura, H., eds., *Proceeding of ISAR'01*, IEEE, Washington DC, 2001, 189.

8. Bass, L., Kasabach, C., Martin, R., Siewiorek, D., Smailagic, A., Stivoric, J., The Design of a Wearable Computer, *Proceedings of the SIGCHI conference on Human factors in computing systems*, ACM, NewYor, USA, 1997, 139-146.

9. Behringer, R., Tam, C., MCGee, J., Sundareswaran, S., Vassilliou, M., A Wearable Augmented Reality Tested for Navigation and Control, Built Solely with Commercial- Off-The Shelf (COTS) Hardware, *Proceedings of the ISAR'00*, IEEE, USA, 2000, 12-19.

10. Builinghurt, M., Proupyrev, I., Kato, H., May, R., Mixing Realities in Shared Space: An Augmented Reality Interface for Collaborative Computing, *Proceedings of ICME*, IEEE, USA, 2000, 1641-1644.

11. Azuma, R., A Survey of Augmented Reality, *Presence: Teleoperators and Virtual Environment*, Citeseer, USA, 1997, Vol.6, Issue 4, 355-385.

12. Woodward, C., Lahti, J., Rökkö, J., Honkamaa, P., Jäppinen, J., Rainio, K., et al, Virtual and Augmented Reality in the digital building project, *International Journal of Design Sciences and Technology*, 2007, Vol.14, No.1, 23-40.

13. Kensek, K., Noble, D., Schiler, M., Tripathi, A., Augmented Reality: An application for Architecture, *Proceedings of the 8th International Conference on Computing in Civil and Building Engineering*, ASCE, Stanford, CA, 2000, 294-301.

14. Phan, V. T., Choo, S. Y., AR: An application for Interior Design, in: Chang, T.W., Champion, E., Chien, S.F. and Chiou, S.C., eds., *Proceedings of the 14th International Conference CAADRIA*, NYUST, Taiwan, 2009, 115-124.

15. Azuma, R., Hoff, B., Neely, H., Sarfaty, R., A Motion- Stabilized Outdoor Augmented Reality System, *Proceedings of the Virtual Reality Conference*, IEEE, Houton, USA, 1999, 252-259.

16. http://www.garmin.com [2-2009]

17. http://www.i-glassesstore.com [2-2009]

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