MOBILE AUGMENTED REALITY FOR SPATIAL INFORMATION EXPLORATION

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Abstract. In this paper, we present an augmented reality system that integrates real and virtual worlds for outdoor sustainable education in campus. We develop a mobile spatially-aware computational device as a visualization aid to students learning outdoors. We apply the mobile augmented reality technology to a newly constructed ecological garden in our campus. Users can virtually see the underlying water cycling system outdoors and map the virtual objects to physical reality through embodied interaction with the computational device. The objective is to make invisible information visible to users to extend interactions with our "living" environment. Keywords : Augmented Reality, Mixed Reality, Mobil Computing, Information Exploration

1. Motivation

Augmented reality（AR）facilitate users to see the mixed world, with virtual objects superimposed upon or composted with the real objects. Augmented reality is a variation of virtual environment, or Virtual Reality (VR) as it is more commonly called (Azuma 1997). VR is a computer-generated world that completely immerses a user inside a synthetic environment.

The objectives of augmented reality are to enhance a user's perception of the real world, and to help people obtain invisible information from surroundings. For example, construction workers could apply AR technique to view the location of pipelines underground to avoid unexpected accident; tourists could use AR system inside a historic building to experience past living style. These objectives are more difficult to achieve in outdoor environment than in indoor embedded systems, because in addition to the difficulties of sensing, tracking, and image calibration, mobile AR system must precisely display information while the user is on the move.

Several solutions have been proposed in the literature to deal with these problems; however, most of them are not satisfactory. The main problems with the majority of the proposed solutions are that they are difficult for multi-users' communication, or give users extra burden and cause them feel heavy even dizzy after wearing the equipment outdoors for a period of time. In this paper, we solve this problem by introducing an alternative design which allows multiple users share the real-time AR images outdoors and is burden free for long-time use.

In this paper, we also discuss the application of mobile AR system for campus educational purpose. We show that if AR system could be applied for outdoors learning, students will obtain more valuable knowledge then before.

The paper is organized as follows. In Section 2, we identify the characteristics of mobile augmented reality system and review the related works. In Section 3, we introduce the concept of outdoor mobile augmented reality for spatial information exploration. We also discuss the prepared-outdoor AR method, a refinement of the non-prepared mobile AR method which reduces the overloading of users. Finally, in Section 4 we provide an example of outdoor mobile augmented device and summarize our results and user experiment.

2. Characteristics of Mobile Augmented Reality

Augmented Reality has following properties:

- ■ combines real and virtual objects in a real environment;
- ■ runs interactively, and in real time; and
- ■ registers (aligns) real and virtual objects with each other.

(Azuma, Baillot, Behringer, Feiner, Julier, MacIntyre, 2001)

Many augmented reality systems that have been proposed for spatial information exploration are not directly applicable in mobile computing environment because of the limitations of data transmission, user position tracking, and personal burden caused by equipment. To illustrate this point, let use consider Table 1 which depicts differences of the requirements between non-mobile AR systems and mobile AR systems.

Table 1. The requirements of non-mobile AR systems and mobile AR systems

Characteristics	Non-mobile AR		Mobile AR	
	Indoor	Outdoor	Indoor	Outdoor
Combines real and virtual objects in a real environment	■	■	■	■
Runs interactively, and in real time	■	■	■	■
Registers (aligns) real and virtual objects with each other	■	■	■	■
Users' loading consideration	□	□	□	■
Long distance sensing and tracking ability	○	□	□	■
Weather condition consideration	○	■	○	■
Natural lighting consideration	○	■	○	■

○ not required □ basically required ■ strictly required

2.1. THE PROBLEM

In the early works in this area the problems caused by mobile augmented reality were not fully recognized.

Feiner (1997) applied AR technique on the device named "Touring Machine" to present information about Columbia University campus, using a see-through, head-worn 3D display and a handheld 2D display. Piekarski (2003) developed a mobile outdoor augmented reality system with a pair of vision tracked pinch gloves, Head Mounted Display (HMD) goggles and a set of new techniques for users to use the physical presence of their body on modeling 3D geometry. Using HMD as a navigation tool is efficient for people to interact with AR environment. However, wearing HMD also brings additional burden to users' heads and causes users feel dizzy after a period of time. In such a situation users could not share their views and experiences with others, which is inconvenient for group participation or discussion. To overcome these difficulties, Schnädelbach (2002) develop a portable mixed reality interface for outdoors called "Augurscope". Nevertheless, Augurscope only displays the view as a virtual environment that is aligned with the physical background.

2.2. RELATED WORK

The solutions to the problems of mobile augmented reality that have been proposed in the literature can be divided into several groups:

3D AR display -- (Rekimoto, 1997) (Feiner, 1997)
Image registration and calibration – (Höllerer, 1999) (Starner, 1997)

User position tracing – (Höllerer, 1999) (Feiner, 1997)
Collaborative interface – (Baillot,2001) (Piekarski, 1999)
Wearable computers – (Behringer, 2000) (Mann, 1997) (Feiner, 1997)

2.3. AN EXAMPLE

In this paper, we attempt to establish an AR system for outdoor educational purpose and use the system as a knowledge-exploring medium of the ecological garden in our campus（Figure 1.）. The system provides visualization aid to students learning outdoors, which could help students to understand the mechanism of the sustainable campus. In this application we have four design criteria which are as follows:

1. For multiple users
2. Users could share real-time AR images
3. Applied outdoors
4. Is burden free for long-time use

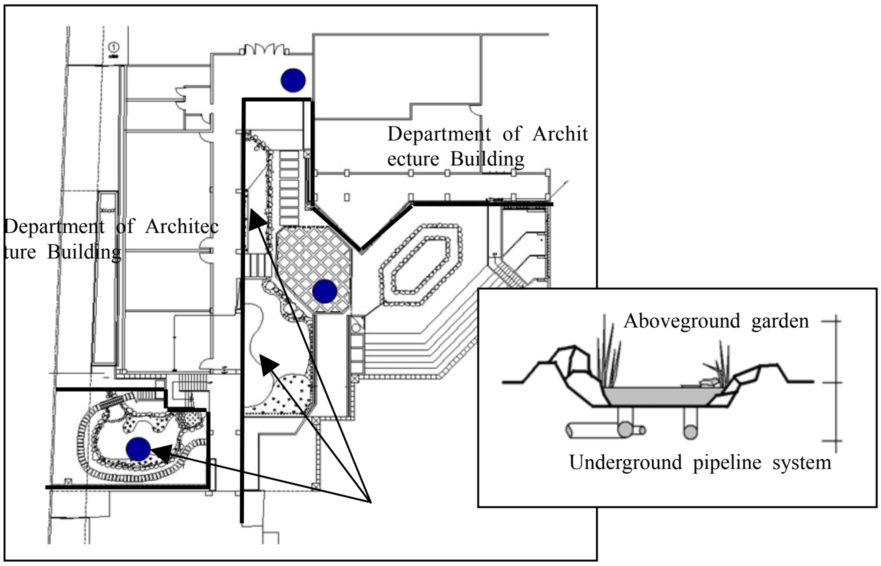

Figure 1. The ecological garden in National Cheng Kung University, Taiwan

3. The Mobile AR Method

In this section we describe a method for mobile augmented reality, which guarantees burden-free for multi-users with the outdoor environment well prepared.

The proposed method addresses three complementary issues:

1. How the mobile AR system can compose the real-time images in the physical world and the panoramic view of underlying building infrastructure in the virtual world,
2. How the mobile AR system can tract the user's position and to provide a computer-generated representation of mixed reality in real time, and
3. How do we allow the user interacting with the mobile AR system outdoors in an intuitive manner.

3.1. MIXED REALITY: COMPOSING PHYSICAL AND VIRTUAL IMAGES IN REAL TIME

The mobile AR system has two operation modes: *fixed-location mode* and *mobile mode*. In fixed-location mode users could view the display of virtual 3D objects overlaying on real-world 3D objects and combining with text information. While in mobile mode, users only could view the text information showing beside the image of real-world objects.

We create pre-made virtual objects and use authoring tool to establish the background stage. While the embedded web cam captures physical image, the image will be shown on the background stage and the pre-calibrated virtual 3D objects will show up to generate overlay images in real time.

3.2. TRACKING THE USER'S POSITION

In the mobile AR system, fixed-location mode needs higher precision on registration than mobile mode. For the first time setting up the system in fixed-location mode, it requires manual adjustment for the registration of virtual and real-world 3D images. However after a period of users' manipulation such as looking up and down, rotating left and right, the two sorts of images might start to mismatch due to the displacement of mechanical parts. At this time, it needs manual calibration again. In mobile mode, the method of registration is comparing real-word images entered into the central area of the screen with the images in database in real-time. If the compared two images are closely looked like, then the text information will be shown on the screen besides the real-world images. In the mobile mode, even there is a little shaking or tilting still will not affect the image recognition.

To improve the static errors happened in fixed-location mode, we need to improve the precision and stability of mechanical parts in order to avoid the parts looseness. Besides, we plan to develop a software system that can automatically calibrate the virtual 3D images to align the real-world images when the system detects there is a mismatch on the display.

3.3. OUTDOOR MOBILE INTERACTION

Since this AR system apply a tablet PC with touchable screen as major displaying device, users could directly write personal notes or marks on the screen as well as point on the screen to save and download data into the portable flash memory. This allows users to share experience and communicate with each other, which is helpful for group discussion in outdoor education.

4. The Application

4.1. THE IMPLEMENTATION

The system is implemented in an information station located at the ecological garden. Users can plug a tablet computer into the display set to explore surrounding environment. If there are obstacles such as walls or buildings occlude the line of vision between users and the target object during the spatial exploration, users could adjust the focus of the display to see through the obstacles into a virtual world and keep on searching in that virtual environment.

The prototype I of this system adopts HP TC1000 tablet PC with a Logitech web cam mounted on it. (Figure 2.) The optional support structure composed of an extensible arm, a rotatable deck, and a set of adjustable tripod to provide a better flexibility and adaptability. We create pre-made virtual environment and apply authoring tool to establish the background stage and real-time overlay images.

Figure2. Prototype I of AR system

4.2. USER EXPERIMENT

Currently, this mobile AR system is applied to the newly designed ecological pond in National Cheng-Kung University campus. Users are able to visualize 3D augmented-reality images demonstrating the underlying function of the ecological pond through this spatial exploration system (Figure 3. & 4.). Users also could operate this system to move around on its axis for acquiring the information of surrounding buildings.

Figure 3. Users could directly write personal notes or marks on the screen as well as point on the screen to save and download data into the portable flash memory

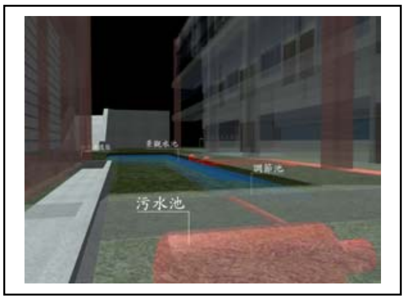

Figure 4. The overlapped real and virtual image on display

Furthermore, due to that fixed-location mode only provide users to face the observed real objects in a limited viewing scope, this AR system also provides a mobile mode to overcome this weakness. Users could detach the tablet PC and bring it walking around. If the user reaches a pre-marked observing point, then he/she could hold the PC and scan around the ambient environment (Figure 5.). When the particular real object with information are scanned and displayed at central area of the screen, then the embedded information of that object will present in real-time. This mode not only could broaden the exploring angle for users while observing particular objects, but also could let users to bring the tablet PC with him/herself and reuse it in different pre-marked information points or information stations within the campus.

Figure 5. The user could detach the tablet PC and scan around the environment to obtain spatial information.

Currently the system works well on fixed-location mode, but the implementation of mobile mode is still undertaken. We encountered the problems of dynamic image recognition and now are testing new software programs to obtain better results.

5. Conclusion and Future Work

This paper addresses two major research issues in mobile augmented reality. One is to create a burden-free environment and to provide a computer-generated representation of reality in real time. The other issue is to compose the video of real world and the panoramic virtual model of underlying infrastructure outdoors, allowing multi-users to interact with mixed reality in an intuitive manner.

Our observation of the experiment concludes that a mobile AR system allowing multiple users share the real-time AR images outdoors and is burden free for long-time use is a greatly needful and helpful tool for education.

This research is part of a long-term project called “Sustainable Campus” in National Cheng Kung University in Taiwan. This project will concatenate four main points including Campus Library, Ancient Small West Gate of Tainan City, Banyan Garden, and Ecological Garden as a major axis of the campus development. This axis contains plenty knowledge of history, ecology, and technology. Therefore, in the project will constructs four information stations at this four major points for people in the campus to explore these valuable embedded knowledge. In the future the AR system in this research is planed to be constructed in the information station and take the station as the fixed mode operation location. Furthermore, people also can carry the AR system along this major axis and apply the system as an interactive tool for spatial information exploration.

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