

Information display for mobile augmented reality

Merging the real and virtual world

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Abstract

Mobile augmented reality requires accurately alignment of virtual information with objects visible in the real world. We describe a system for mobile communications to be developed to meet these strict alignment criteria using a combination of computer vision and inertial tracking techniques. We discuss the use of the system to display information retrieved from 3D GIS databases and the world-wide web.

1 Introduction

Mobile augmented reality [1,2] is a relatively new and intriguing concept. The ability of augmented reality [3] to present information superimposed on our view on the world opens up many interesting opportunities for graphical interaction with our direct environment. Combining this with mobility further increases the potential usage of this technology for direct daily use.

However, the technical problems with mobile augmented reality are just as great. As with other head-mounted display systems, augmented-reality displays also require an extremely high update rate. Simple head movements may in short time give rise to significant changes in viewing position and viewing direction. The virtual information associated with objects in the scene and displayed within the viewing window will then have to be updated to maintain the proper alignment with the objects in the real world. The viewpoint changes will therefore have to be tracked and fed back to the display system, in order to re-render the virtual information in time at the correct position.

Padmos and Milders [4] indicate that for immersive reality (where the observer can not see the normal world), the update times (lag) should be below 40 ms. For augmented reality the constraints will be much stricter. They suggest that the displacement of objects between two frames should not exceed 15 arcmin (0.25°), which would require a maximal lag of 5 ms even when the observer rotates his head with a moderate speed of 50°/s. Several other authors use a similar approach [5-9] and come to similar maximal lag times. Actually, during typical head motions speeds of up to 370°/s may occur [10], but it is not likely that observers rotating their head that fast will notice slight object displacements. Many authors suggest that 10 ms will be acceptable for AR [5,11,12]. Summarizing, we may say that the alignment criteria both for accurate positioning and for time lag are extremely high.

In this paper we describe how these strict requirements could be met and we present some initial ideas about presentation of graphical information with mobile augmented reality. In section 2 we first describe the context of our research, the Ubicom project, a multi-disciplinary project carried out at Delft University of Technology, which aims at the development of a system for Ubiquitous Communication. In section 3 we focus on the problem of image stabilisation and discuss latency issues related to position tracking and display. In section 4 we discuss possible applications of the system and the way information is displayed to the user and how the user can interact with this information.

2 Ubicom system

The Ubicom System [13] is an infrastructure for mobile multi-media communication. The system consists of a backbone compute server, several base stations, and a possible large number of

mobile units. The base stations maintain a wireless (radio or infrared) link to the mobile units. The radio transmission is scheduled in the 17 GHz range and will account for approximately 10 Mbit/s of data bandwidth per user, enough to transmit compressed video with high quality. The cell size (distance between the base stations) is in the order of 100 meter: typically the distance between lampposts to which the base stations may be attached. The system set-up is displayed in figure 1.

The mobile unit consists of a receiver unit and a head-set. The head-set contains a light-weight head-mounted display that offers the user a mix of real and virtual information. This may be realised either superimposing the virtual information on the real world or by replacing parts of the real world with virtual information. In the latter case we need partially visual blocking of the view on the outside world. In addition to the display facilities, the headset will also have a light-weight video camera that is used for position tracking and to record video data. In order to keep the power consumption low, the head-set and receiver unit will only have limited processing and memory capabilities. Figure 2 shows the diagram of the head-set and receiver unit.

Central to the function of the headset is the exact alignment of virtual information with the objects in the real world that the user is seeing. This requires that the exact viewing position and viewing direction of the user are known. Position as well as orientation tracking are therefore needed. Orientation tracking is much more critical than position tracking as a small rotation of the head will have a larger visual impact than a small

movement to the left or right.

Position tracking is done in three steps (Figure 3). A first position estimation is done using GPS or similar position detecting techniques. A possibility is to calculate the position relative to the base stations. A second level of position tracking is using object and scene recognition. Given a 3D description of the environment (e.g. a CAD-model) and an initial position estimate, an accurate position may be calculated iteratively. However, the model data will only be available at the backbone and most of the calculations to derive the viewing position will have to be performed at the backbone as well. Part of this computation could be offloaded to the active base station. The latency introduced by first sending the video captured scene information from the mobile unit to the backbone, then the processing at the backbone or base station and the transmission of the obtained viewing parameters, will be too large for the update of the visual display. Therefore to be able to anticipate on small position changes immediately, the direction and acceleration of the movement will be sensed with an inertial tracker and directly fed back to the display system. In the same way, the orientation tracking will be based on object recognition and direct feedback from the inertial tracker.

Given an accurate viewing position, a new virtual image will have to be generated. Also here the choice is whether to calculate each new image at the backbone with a powerful render engine and to transmit the image to the mobile unit over the wireless link, or to render the image directly by the mobile unit, avoiding the latency of the wireless link. Even for the second option, direct

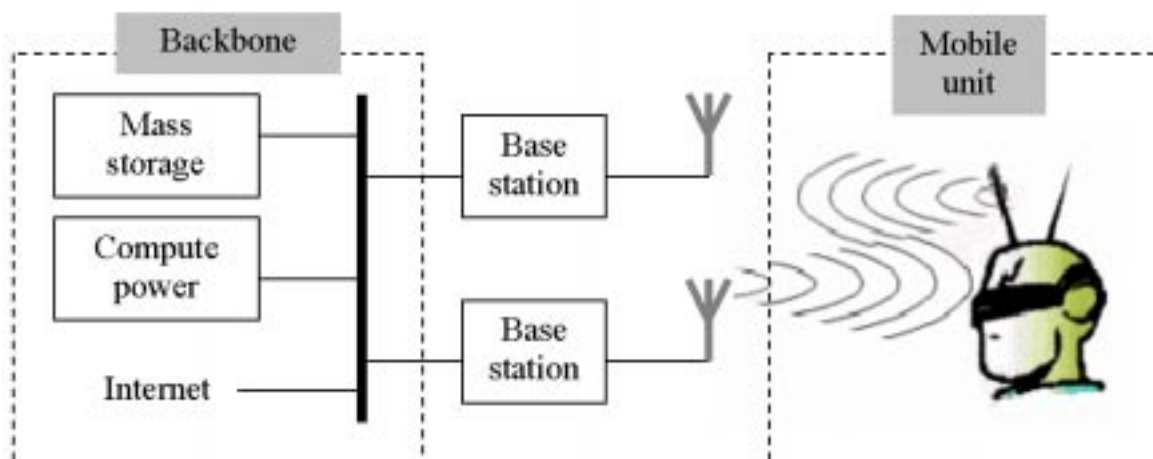


Figure 1: Ubicom system set-up. The mobile unit contains display, camera, and tracking devices, and is connected through a mobile link to one of several base stations. Memory and processing resources are limited in the mobile unit in order to reduce power consumption and extend battery life. Instead, the mobile connection is used to access resources like mass storage and compute power at the backbone.

rendering at the headset, there will be a latency in the order of 50-100 ms, which is unacceptable. To compensate for small changes in perspective and

viewing direction, we could apply image warping and viewport re-mapping techniques [14,15]. To further account for parallax changes, the virtual

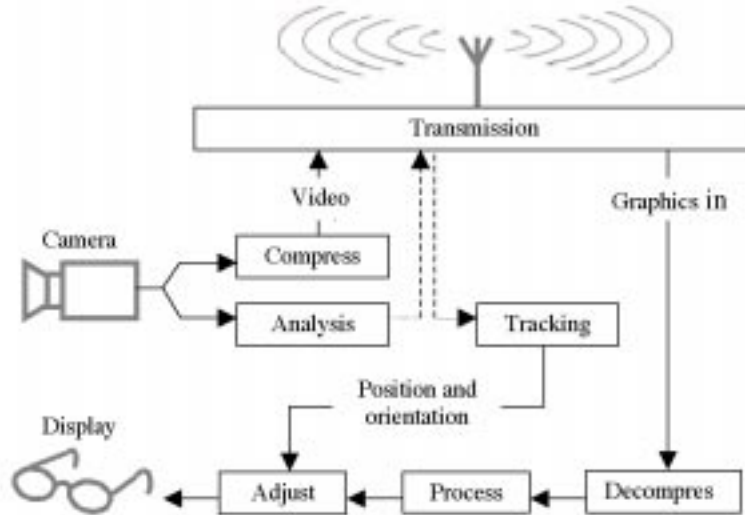


Figure 2: Diagram of the mobile unit. The camera at the mobile unit supports two main functions. First, the camera produces video, which is compressed and sent to the backbone for recording or distribution to other users. Second, the camera images are analysed to find landmarks that are used for position tracking. The actual matching of landmarks is computationally expensive and is done at the backbone. The backbone also supplies the mobile unit with the AR graphics, which must be decompressed and processed before they can be displayed in overlay with the real world. Fast tracking devices in the mobile unit measure the head-motion of the user and track the latest position and orientation of the head-set. This information is used for last-minute adjustments of the displayed graphics, such that these remain in register with the real world.

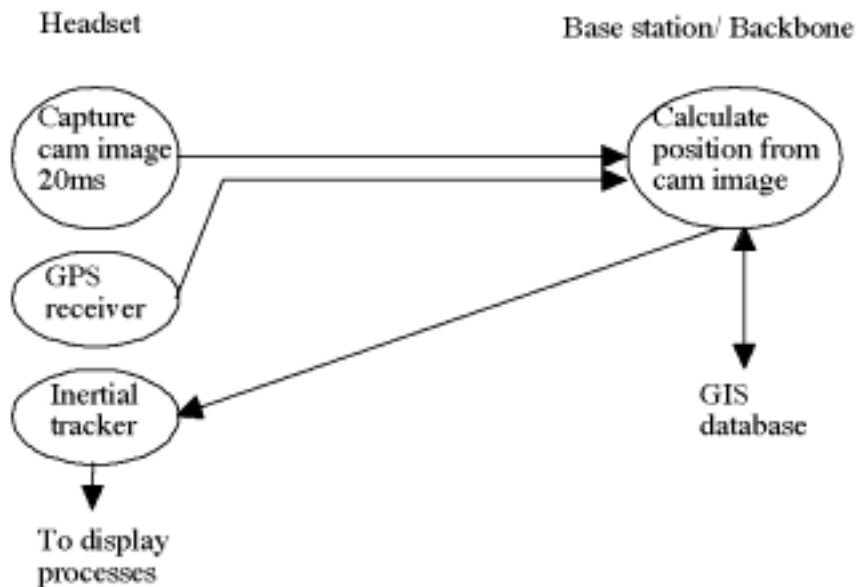


Figure 3. Circles represent processes, boxes local memory and arrows the data flow. Position changes are directly determined with the inertial tracker. To compensate for drift, more accurate positions are calculated regularly in the backbone, based on GPS data and camera images.

and real-world information could be segmented in layers, and the resulting image would be calculated by merging the warped image layers [16]. In order to be able to generate these image layers within certain time constraints, we first segment the model data in model layers to reduce model complexity. The model simplification could be done at the backbone while the image layer rendering - taking into account the current view point - could be off-loaded to the active base station.

3 Latency issues

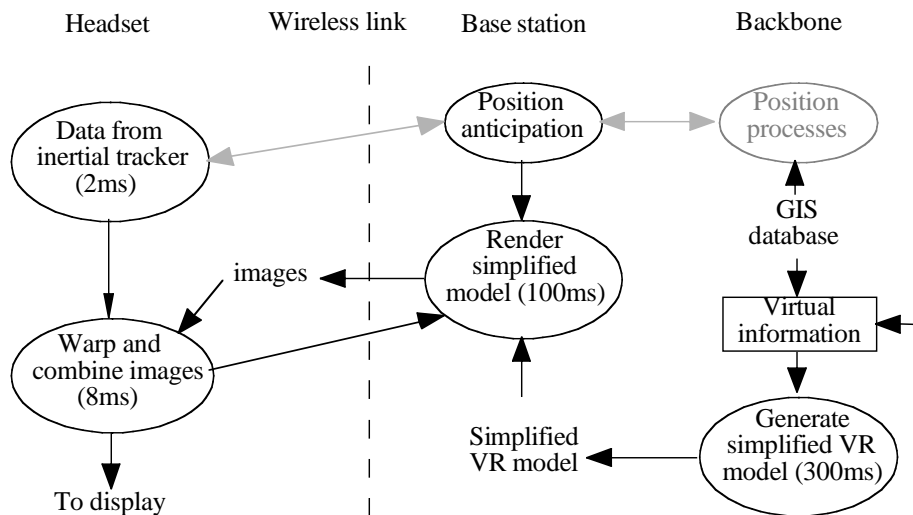
If we analyze the latency of the inertial tracking and corresponding image compensation, we come to the following conclusions (Figure 4).

In global, we have three paths to refresh the image in the head-set with increasing latency times and increasing accuracy: a path local to the headset, a path from head-set to base station and back, and a path from headset via base station to the backbone and back. In the headset we minimise latency by using an inertial tracker (2 ms delay) and image warping and combining (8 ms). The image warping and combining is done just ahead of the display scanning, to avoid latency that might be caused by the refresh rate of the display. In the base station, a simplified virtual world is being rendered to images that can be used in the headset. Either the headset itself requests for these images or the base station anticipates the need for

new images from recent movement data passing through the base station. These new images will have a lag of about 200 ms when arriving at the headset. In the backbone there are two processes. The first calculates the viewpoint of the observer given camera images from the headset and a GIS database. This process may be supported by GPS data acquired in the headset, and may take up to 500 ms including all transmissions back to the headset. The second process is the generation of a new virtual world by generating 3D model layers. Images generated from the new simplified virtual world model rendered at the base station will arrive at the headset with a latency of about 1000 ms, one second.

4 Interaction through object referencing

The big advantage of using mobile augmented reality is the possibility to ask and to display information ‘on the spot’ with reference to the objects in the direct environment of the user. This information could be displayed as 3D objects and symbols merged in the scene, or as text ‘labels’ attached to objects in the scene, or as animated actors or info-bots. As the possibilities by lack of mouse and keyboard to directly graphically interact with the image are limited, most of the conversation will be through a language interface. The combination of speech recognition and synthesis supported by references to both the real and virtual objects in the scene will allow a very



natural form of dialogue.

To be able to provide 'information-on-the-spot', we need an accurate geometric description of the environment, as well as attribute information. A geometric description of the environment could be provided by a 3D GIS system. As 3D data acquisition systems will improve over time, large GIS databases will become available for general use. An important source of attribute information (in digital form) is the world-wide-web. To match these two sources we could link URL's of persons, organisations, and local community services with objects and positions in the GIS system.

A possible scenario would then be that a user walks through an environment. His position would be matched with the GIS database. From the GIS database relevant URL's could be extracted and a dialogue manager would select and retrieve information from the corresponding webpages and translate this information into visual form. Part of this visualisation could already be provided by VRML-like descriptions stored at the webpages. This would allow 'information owners' to decide themselves how other mobile users would 'see' his information.

As the position of each mobile user is accurately tracked, his position could be associated with the GIS database and every other mobile user could defer which users are currently in the same building or same room. Again this would allow a direct information exchange through a www-server.

It is clear that mobile augmented reality offers exciting new opportunities for data communication and remote personal communication. However there are also a lot of user interface issues that still have to be sorted out. We already mentioned the technical issues with respect to registration and alignment. However, there are as much other perceptual and cognitive issues that have to be researched with respect to overlay contrast, visual blocking (and have the chance of accidentally blocking incoming cars), and whether the virtual information is recognized as virtual instead of real, etc.

5 Current state of the project

A first prototype system will be operational early 1999. This system will consist of ordinary PC's with off-the-shelf DSP boards. It will have a limited portability, an experimental infrared mobile link, and it will use a standard look-

through head-mounted display. The system will be tested within our research lab environment. As a first demanding test-case we develop a toy-application, which implements an AR version of the well known Pacman video-game. The system will use a small ad-hoc database containing the geometric description of a few rooms. Later in 1999 a full 3D GIS model of the University campus will become available which will serve as a geometric reference for an outdoor application, e.g. way finding.

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