Chloe@University: An indoors, HMD-based mobile mixed reality guide

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Abstract

This paper describes an indoors, mobile mixed reality guide system: Chloe@University. With a see-through head-mounted display (HMD) connected to a hidden small computing device, Chloe@University provides users with an efficient way of guiding in a building. Augmented 3D virtual character in front of a user guides him/her to destination so that he/she can just follow the virtual guide after the user gives a voice command with desired destination to it. The most suitable virtual character is selected depending on a user's preference for personalized service. For adapting to different indoor environments, the proposed system integrates various localization approaches. In addition, it supports different access right to a building map based on user profiles and security level.

Categories and Subject Descriptors
I.3.7 [**Three-Dimensional Graphics and Realism**]:

General Terms
Algorithms, Experimentation

Keywords
Real-time systems, Mixed Reality, Virtual Human, Localization, Sensor Networks

1. Introduction

With the advent of ubiquitous and pervasive computing environments, one of promising applications is a guidance system. Even though existing navigation approaches show a user right way to his/her destination with simple arrow signs in a 2D map, users are confused with which way they should go because they always has to figure out now where they are in the map. It brings an improved guiding method by augmented reality with which it gives ways to destination superimposed over real roads and buildings. However, they still lack personalization and user-friendly interfaces as users should always carry computing devices equipped with camera, and various sensors.

In this paper, we propose a mobile mixed reality guide system for indoor environments, Chloe@University. A mobile computing device is hidden inside a jacket and a user selects a destination inside a building through voice command. A 3D virtual assistant then appears in the see-through HMD, and guides him/her to destination. Thus, the user simply follows the virtual guide. Chloe@University also suggests the most suitable virtual character (e.g. human guide, dog, cat, etc.) based on the user's preferences and profiles. Depending on user profiles, different security levels and authorizations for content are previewed. As indoor location tracking is an active field of research, WiFi, RFID, and other sensor-based methods are proposed and integrated in this system.

The remainder of this paper is organized as follows: Section 2 describes related work about indoor/outdoor guiding systems. In section 3, we propose our detailed approach. After we explain how our first trial is implemented in section 4, section 5 concludes the paper with further work.

2. Previous work

Mobile AR systems have been widely employed for mobile navigation assistance. Such systems typically involve a mobile h/w device such as PDA, ultra-mobile PC (UMPC) or laptops, based on an integrated AR platform allowing for multimodal navigation AR aid while traversing physical buildings or outdoors locations. However, different approaches are followed based primarily on whether indoors or outdoors AR navigation is needed: Hollerer and Newman et al work indoors while Bell et al and Reitmayr et al are employed outdoors. Absolute tracking and registration remains still an open issue and recently it has mostly been tackled by no single method, but mostly with an aggregation of tracking and localization methods, mostly based on handheld AR. A truly wearable, HMD based mobile AR navigation aid for both indoors and outdoors with rich 3D content remains still an open issue and a very active field of multi-discipline research.

Due to the fact that networked mobile AR users are enabled with wireless radio communication network interfaces (such as WiFi), protocols that provide location estimation based on the received signal strength indication (RSSI) of wireless access points have been recently becoming more-and-more popular, precise, and sophisticated. The main benefit of RSSI measurement based systems is that they do not require any additional sensor/actuator infrastructure but use already available communication parameters and downloadable wireless maps for the position determination. Their shortcoming for mobile AR is precision, often multiple access points as well as tedious training offline phases for the construction of the wireless map. Peternier et al employed a WiFi localization based method for a PDA-based Mixed-Reality system for visualizing virtual character 3D

content, where Liu et al describe a wifi localization algorithm based on a single access-point infrastructure as navigational aid.
A very recent trend in mobile AR systems is the usage of Ultra Mobile PCs, based on the Microsoft Origami™ specifications in 2006. Those powerful, mobile small-factor tablet PCs employ similar operating systems as tablet PCs but in a small-scale factor, resembling large PDAs. A number of researchers have started employing them in AR simulations such as Wagner et al and Newman et al.
Before the very recent introduction of UMPCs or SmartPhones with CPUs of significant computational capacity, Personal Digital Assistants (PDAs) were the only truly mobile alternative for AR researchers. However, a number of computational issues make difficult their employment such as lack of dedicated 3D capability and floating point computational unit. Reitnayr et al, Wagner et al, have all employed them as handheld display devices for AR applications, whereas Makri et al and Peternier et al allowed for a custom-made connection with a special micro-optical display as an HMD.

3. Our approach

In this section we describe the different modules that we integrate in our solution (see figure 1).

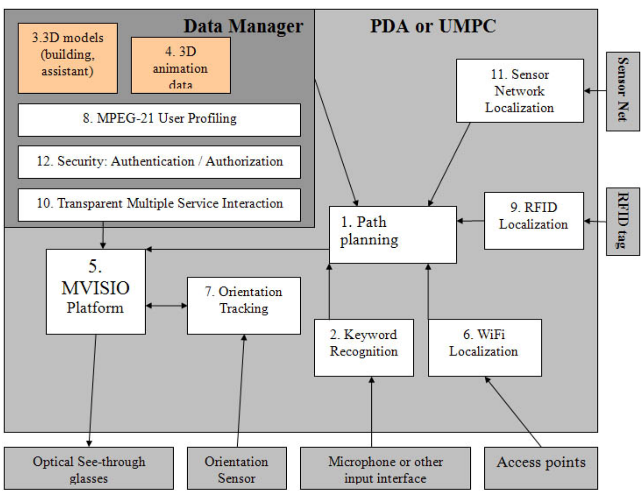

Figure 1: Modules overview

3.1 Virtual Guide Simulation and 3D display

Augmented Reality based virtual guides require robust, cumbersome and complex platforms to be adopted, mainly because of the fine accuracy required to blend virtuality with reality. We decided to adopt a mixed reality approach, less constraining. By using several tracking technologies (see section 3.3) we can determine the approximate position of the user, with a precision ranging from ten to one meter. This information is used to determine an area of interest surrounding the user. This way, we show a world-aligned fly-by 3D reconstruction of this area (rooms, walls, hallways, etc.) on the HMD. This 3D view always follows the same orientation as the real building, thanks to the orientation sensor (see 3.3.1). A virtual human moves in this 3D environment showing the user the path to follow. Our approach allows Chloe@University to always give useful feedback independently from the accuracy of the tracking, because the area of interest will always display a portion of the building wide enough to contain the user real position (even if few meters away from the tracked one) thus giving relevant information. The application automatically detect zones with low tracking accuracy and adapt this area of interest range by zooming in or out dynamically. Thanks to the 3D models being oriented with the reality, users can immediately match the abstract information displayed on the HMD with the surroundings.

3.2 Path planning and user interaction

To guide a user, the system needs first to determine the path to follow from the source to the destination. If the user deviates from his/her original way, this path has to de updated accordingly. To compute the path in an efficient manner, a dedicated version of the A* algorithm was implemented. To represent the map a graph storing position and links is used. Figure 1 shows a model of the building along with the map used path finding. For this purpose a tool was developed within the authoring application 3D Studio MAX to edit the map.
How one obtains the user's destination, depends on the capabilities of the device used. Given the computing capabilities of the UMPC, speech recognition will be used. A speech to text commercial product will be used; the output is then compared to the entry of a database storing target information: name, occupation, position…

3.3 Fusion of tracking methodologies

The purpose of localization is to provide some kind of location information for nodes in a sensor network. It can be used to identify an unknown mobile node for application requirements and/or to support routing algorithms. To do this, we use three different techniques that we enable/disable or combine according to the context and location of the user in order to improve localization in areas where one of them would lack of accuracy.

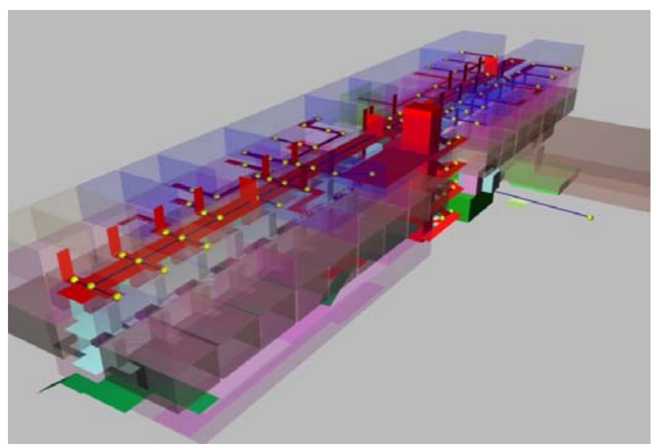

Figure 2: building with graph for path finding represented as spheres and cylinders

3.3.1 Orientation tracking

As has been noted, any non invasive indoor localization is not precise enough to be able to display convincing AR. For this reason, we chose to render a 3D map displayed on see-through glasses in third-person view as seen on figure 2.
The idea is to point the user to his destination in the same way it would have been done with a traditional GPS navigator.

Therefore, the map is always following the same orientation as the user. In other words, what the user sees in front of him in the see-through glasses is in fact in front of him.

3.3.2 Sensor network localization

A major advantage in using sensor networks for localization purposes is that sensor networks may already be available in the environment to acquire context information, thus there is no need for additional hardware. Secondly the sensor networks often employ localization on their own for their own purposes (for instance to relate the context information to the actual position).

We consider a range-based localization system which computes the location of the sensors based on the estimate distance from (previously deployed) anchor nodes whose actual position is known. We estimate the distances based on the RSSI parameter. In particular a generic mobile sensor emits periodic beacon packets. Each anchor receiving the beacon computes the RSSI indicator and gives this information to the main anchor (also called sink). The sink in turn forwards this information to an attached PC which performs the localization algorithm.

The localization algorithm first approximates the distance between the mobile sensors and the anchors based on the lognormal propagation model applied to the received RSSIs. Then it uses this information to approximate the location of the mobile sensor in the environment using a standard multilateration technique. To this purpose the algorithm also uses pre-loaded information about the environment (position of the wall, room size, etc…) and the position of the anchors.

3.3.3 Wifi Localization

This localization system presents a big advantage : it runs on any WiFi-enabled device and makes use of pre-existing WiFi access points. For the Chloe@University project, we need a localization system which provides a room-sized precision and a high accuracy.

Our system works in two phases: the off-line phase which consists in collecting signal strength data in order to build a signal map, and the real-time phase, corresponding to the localization phase and based on the previously acquired signal map. During the off-line phase, the user creates a navigation graph: each room (or part of corridor) is represented as a vertex of the graph, then the user has to link neighbour vertices between them and records signal data (access point identifiers and signal strengths) for each vertex.

After this quick training phase (30 seconds per vertex to capture signal data), the localization system is ready to use: the application takes WiFi samples every 250ms, locates the user (by a simple distance calculation) according to the signal map acquired during the off-line phase. The system uses the navigation graph to ensure that the new position is realistic (close to the previous one), and then avoid the biggest mistakes due to signal noise.

3.3.4 RFID localization

We also used a prototype radio frequency identification (RFID) positioning system in our project. It may work as an alternative to the other positioning engines or in collaboration with them in order to provide improved coverage and accuracy especially in confined spaces where the signal strength of the WiFi access points (APs) or sensors network is diminishing.

The position is realized using a computing device equipped with a single RFID reader and multiple tags placed in fixed locations which act as beacons to obtain the position of the computing device.

Each tag has a unique identification. When the reader is within the transmission radius of a tag, the tag will send a packet with information such as its unique ID, RSSI, age of the tag in seconds, the Site Code which is a unique identification per company or system using the equipment and the tag type.

For our RFID localization system we opted for using active tags. Active tags, as opposed to passive tags, contain a build-in battery which runs the micro-chip's circuitry and powers the transmitter that broadcasts a signal for the reader to read. Active tags due to their own power supply can provide us with an amplified signal which increases the reading distance of the tag compared to the reading radius of passive tags which is relatively short.

In order to make our positioning system even more accurate, we are using a triangulation algorithm to estimate the position of the device instead of simply using the location of the tag with the strongest signal the reader receives.

3.4 Smart and Transparent seamless connectivity for advanced mobile services over WiFi

Wireless Network connectivity in the Chloe@University scenario faces many practical challenges, as it is quite impractical to deploy a dedicated wireless network that completely covers a wide environment such as a campus. On the contrary, in realistic applications, Access Points (APs) deployed for specific laboratories or offices will be used to serve mobile users as they come in their proximity; unfortunately, this poses the problem that guest users gain access to internal networks on which sensitive traffic may be transferred (for example, confidential research information and personal data in accounting offices).

The proposed approach provides for “open” APs at the campus entrances; they continuously transmit information about the location and available services. Once the user has supplied the required credentials and authentication has completed successfully, his device receives a set of connection parameters, including an IP address, a Mobility Management Server (MMS) reference, a shared secret, etc. From now on, security should rely on the 802.11i mechanisms, holding the MMS also the functionalities of the Authentication Server. This approach is basically *zero-configuration*: no manual intervention is required to the user, apart the case his authentication information is not stored in his device. The outlined solution assures the independence and privacy of guest and local traffic, but it does not account for seamlessly roaming yet.

Roaming between APs (even through different ESS) essentially concerns a quick handoff procedure. The MMS knows location, coverage area and operational parameters of all APs in the campus and can aid the guest device to select the best AP to associate with; the choice can be based on several metrics, as the signal strength, the user path, the traffic load, the QoS capabilities and eventual management restriction (to deny access to most critical networks). The aim is to serve at best the mobile device, while minimizing the handover in order to reduce system overload and reduce or avoid service interruption. In a campus-wide scenario like that one proposed, the whole network infrastructure (and therefore the APs) is very likely to be partitioned into small subsets, matching different organizational units; we envisage the creation of a specific IP subnet for guest users and the usage of a dedicated Virtual LAN (VLAN) between the whole AP set and the MMS: this is essential to avoid any IP-based roaming mechanisms (as Mobile IP) that would inject intolerable delays into the handover procedure. Moreover, the same approach is useful to keep the guest traffic behind a firewall, so to maintain a very fine control on connections from mobile users towards the local network and the Internet and vice versa.

4. Implementation

Implementation is planned in two steps. A first prototype is carried out supporting basic functionalities and meant as a basis for the whole project.

The system relies on mobile and compact devices. For our tests, we targeted two different hardware and software architecture: the first one running on an ultra-mobile PC Sony Vaio UX70 (Windows XP/Vista), the second one running on a Dell Axim x50v PDA (Windows Mobile 5). We used a Liteye-500 monocular see-through head-mounted display in both setups. The main core is written in C++ using a dll-based pluging system and the MVisio graphics engine (http://www.exence.ch). Each localization technology features a shared interface accessed through dynamically loaded DLLs: switching from one technique to another is just a matter of load another DLL and rebind the methods. So far, the whole platform is running onboard of the UMPC or PDA (in step two the data manager will be moved to a remote server).

Orientation tracking has been achieved using the MTx inertial sensor from XSens, over USB or Bluetooth for wireless transmission. This sensor is attached on the HMD as we need to map the pitch and yaw information to the orientation of the map displayed in mixed reality.

4.1 Early tests

First indoor localization experiments using the WiFi network have been conducted inside our laboratory. The results showed that the precision was limited to minimum 5 meters. However, it proved a remarkable consistency for locating the user in the radius of a room.

A second series of tests performed in real contexts showed that the necessary parameterization task can easily be performed in less than 5 minutes for an optimum localization performance.

The hardware (UMPC, see-through HMD, inertial tracker, batteries) we used for this experiment fits in a large pocket and is relatively unobtrusive during normal day-to-day activities.

5. Conclusions and Future Work

One main limitation of 3d modelling and the displaying of 3d content is that it consumes a lot of processing power. With the boom of graphics chips the technical possibilities are growing in a lot of different directions. But running those applications in an extended home environment is problematic due to the large amount of potential platforms the applications have to function on.

Given a high enough connectivity, computational demanding operations could run on the server side thus allowing the use of less capable machines at the client side. In this light, displaying complex, physically based scenes could be achieved on any kind of hardware with simple display capabilities. In this scenario we are especially thinking about computing real-time physically based cloth simulation using capabilities of the graphics chips on the server side in order to transfer the outcome to our virtual human.

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