A QR Code-based Indoor Navigation System Using Augmented Reality

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1. Introduction

Significant developments in locational technologies and in the power and size of mobile devices have brought advanced portable location-aware systems into our everyday life. Navigation systems are one of the more common location-aware services, and many people use them on a daily basis. Providing location information through a user-friendly interface is crucial in a navigation system, as is the accurate determination of user locations and target locations. Global Positioning System (GPS), which offers maximum coverage, has been widely used to provide location information since Selective Availability (SA) was turned off in 2000 (Yanying Gu et al. 2009). However, it is well-known that GPS performs too poorly inside buildings to provide usable indoor positioning (Kjærgaard et al. 2010; Yanying Gu et al. 2009; Hui Liu et al. 2007; Ran et al. 2004). It is for that reason that indoor navigation systems are considered much more challenging than outdoor navigation systems (Mautz 2009). Commercial and research-based organisations have therefore carried out a large number of indoor positioning and navigation projects (some of which I will present in the paper) (Kray & Baus 2003; Hui Liu et al. 2007). Most past and current indoor navigation systems are electronic sensor-based, relying on infrared, ultrasound, radio frequency, and so on (Mautz 2009; Yanying Gu et al. 2009; Hui Liu et al. 2007), all of which necessitate an extra installation cost. I believe that not all cases should require high-resolution indoor positioning systems.

On the other hand, proving a user-friendly interface in a navigation system is vital to reducing navigation errors, as well as the time required for a user to understand that navigation information. Augmented Reality (AR) is particularly well-suited as a user interface for location-aware applications (Hollerer et al. 1999; Reitmayr and Schmalstieg 2004). AR is a variation of the virtual environment (Azuma 1997; Höllerer and Feiner 2004). The recent appearance of smartphones featuring GPS receivers, digital compasses, and accelerometers has made it more feasible to build practical AR applications for mobile devices (Jang and Hudson-Smith 2010). One of the benefits of using AR in location-aware applications is that it can provide an intuitive and user-friendly interface (Wagner et al. 2005). This is possible because an AR interface dynamically superimposes interactive computer graphics images onto objects in the real world (Poupyrev et al. 2002).

In this paper I am using QR code (QRcode.com) to determine the user’s current location and collaborating internal Point Of Interest (POI) data to provide indoor navigation information. I also present a scenario-based approach to develop a mobile AR indoor navigation system which could be used in defined areas such as museums or exhibition centres.
2. Related Work

Many researchers have explored indoor positioning systems while other researchers have investigated how to combine AR interfaces with locational information. Technologies such as Assisted GPS (A-GPS), Infrared, Ultrasonic, and Radio Frequency Identification (RFID) are commonly used for indoor positioning. SnapTrack (Moeglein and Krasner 1998) and Locata (Barnes et al. 2003a) were developed for indoor and outdoor positioning using AGPS technology. SnapTrack uses location servers as an assisted GPS, which means that it receives and stores data from the GPS reference receiver while it is on the network, thereby providing necessary data to mobile units, and it calculates navigation solutions upon receipt of pseudorange measurements from the handset. Locata consists of LocataLite (a time-synchronised pseudolite transceiver), LocataNet (a network), and Locata (a mobile device), and it performs with centimetre-level precision (Barnes et al. 2003b). SpotON (Hightower et al. 2000) and LANDARC (Location Identification based on Dynamic Active RFID Calibration) (Ni et al. 2004) are active RFID-based indoor positioning systems. They provide sub-1m³ voxel and 2m accuracy respectively. Active Bat (Hazas and Ward 2002) uses ultrasonic technology which measures the distance between a tag and a receiver based on the time-of-flight of the ultrasonic pulse, and uses that data to compute each tag’s position. The Active Bat system also provides a user’s directional information. In addition, Wireless Location Area Networks (WLANs) (Bahl & Padmanabhan 2000; Smailagic et al. 2000; Youssef et al. 2003) have been frequently used as indoor positioning systems.

The touring machine (Feiner et al. 1997) is a wearable computer-formed outdoor AR system which provides building and accessing information in Columbia University. This system is the one of pioneers in AR outdoor systems, and it annotates the world with overlaid textual labels. Thomas et al investigated an outdoor AR navigation system using a see-through head-mounted display which displayed compass information, distance, exact direction in degrees true, and directions on the screen (Thomas et al. 1998). Context Compass (Suomela and Lehikoinen 2000) shows filtered POI data which may interest a user. Hollerer et al (Hollerer et al. 1999) studied four types of mobile outdoor and indoor AR interfaces: an outdoor User Interface (UI), a handheld map UI, an Indoor UI, and an indoor/outdoor interaction.

3. Scenarios and Functionality

3.1 Scenarios

The following scenarios were created to show specific situations that would not require high-resolution indoor positioning systems. I present two scenarios below:

3.1.1 Scenario 1: Mr. Park Visits an Office to Obtain Feedback for His New Application

Mr. Park is visiting the Centre for Advanced Spatial Analysis (CASA) at University College London (UCL) to obtain users’ feedback on how to improve his newly launched application. He needs to give interviews to about 20 people at CASA. He has a list of the application users but he does not know where each user’s desk is located. He does not want to disturb other people who do not use his application. Mr. Park downloads CASA-ARNavi app from the mobile application market and scans a QR code from the seating plan on the CASA entrance board to find his users’ desks. This scenario highlights the potential of using QR codes for indoor AR navigation systems. Installation of a QR code is very low cost and easy to implement. Such codes can be installed in places where people change directions so as to
identify the user’s current location, match that with each collaborating user’s desk location, and combine that data to provide navigation information in an AR view. That AR view would be very intuitive so as to reduce navigation error and the time required for a user to understand the navigation information he is being given.

### 3.1.2 Scenario 2: Mr. Park Visits The National Gallery to See Impressionism

Thanks to the CASA-ARNavi app, Mr. Park finished his user feedback interviews much earlier than he had planned. He decides to spend his spare time visiting the National Gallery before he returns to Korea. He doesn’t have enough time to see the entire gallery, and he is interested in the post-impressionist paintings. He wants an indoor navigation system to lead him to each of the post-impressionist paintings, so he downloads the National Gallery-ARNavi app and chooses “post-impressionist paintings” on the dropdown menu. QR codes are attached to every painting in the gallery, so once he chooses the “post-impressionist paintings” option, each painting he visits gives him directions to the next post-impressionist painting. In addition, the National Gallery installed QR codes on every signpost so users can receive directions to other POIs. The full data are not typed on signposts due to a lack of space. This scenario highlights the potential of using a QR-based indoor navigation system that can be used with filtered POI data and that can provide an efficient routing to see each POI. It could be equally useful in defined areas such as exhibition centres, museums, shopping centres, and so on.

### 3.2 Functionalities

These scenarios use QR codes to identify a user’s current location. Traditional tag-based AR systems often use a specially-designed pattern (a fiducial marker) to superimpose virtual objects and to determine the registration location. The main benefit of using QR codes (rather than conventional fiducial markers) is that QR codes can be generated without limit whereas fiducial markers are limited in number (Fiala 2007). In addition, AR codes are known as universal barcodes, whereas fiducial markers perform stand-alone (Kan et al. 2009). In this paper I generated QR codes which included geo-coordinates of each location where they would be installed.

The common functions in the two scenarios are the decoding of QR codes and the ability to provide directions in an AR view.

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<td>Display the list of POIs</td>
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<td>Decode QR code</td>
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<td>Display direction information in an AR view</td>
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<td><strong>Scenario 2</strong></td>
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<tr>
<td>Decode QR code</td>
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<tr>
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<td>Order the List of POIs by distance from the current user location</td>
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### 4. System Design and Visualisation

Figure 1 gives an overview of the system design for the QR code-based indoor navigation systems made for this research. In this research I use the Android platform (Android 2.3:
Gingerbread) and Java. The Samsung Galaxy Nexus S has been used as the mobile device. The Galaxy Nexus S has a 1 GHz ARM cortex A8-based CPU, 512 MB RAM, a 4-inch glass touchscreen, and a 5-megapixel rear camera. In order to decode QR codes I used the Zebra Crossing (ZXing) library, which is an open-source, multi-format, 1- and 2-dimensional barcode image processing library (code.google.com/p/zxing/ 2011).

The POI data was built in the JSON format, and figure 2 shows how the contents of the data were used for this application. Figures 3 shows the interface of this application. A user selects the POI/category which may be of interest to him/her (figure 3(a) and (b)), and after that the application decodes the QR code to indentify the user’s current location (figure 3(c)). Finally, directions are shown on the AR interface (figure 3(d)).

5. Conclusion and Future Work
In this paper I have constructed two scenarios that use QR codes to give indoor positioning data to navigation systems that have an AR interface. In cases where high-accuracy positioning is not required, QR codes could be the cheapest and easiest positioning method for an indoor navigation system. An AR interface could be a new visualisation method for GIS data such as POI locations, directions, and so on. In addition, an AR navigation system
can be efficiently implemented within defined areas such as university campuses, shopping centres, museums, and so on. Today’s mobile application ecosystem allows users to download mobile applications ubiquitously.

There are many directions in which I would like to extend this work. Firstly, there have been several attempts to develop a seamless indoor/outdoor navigation system (Thomas et al. 2000; Ran et al. 2004). I plan to combine the indoor AR navigation system that I presented in this paper with the outdoor AR navigation system in my previous work (Jang and Hudson-Smith 2012). Secondly, even though AR has been considered the ultimate user interface (Sutherland 1965; Hollerer et al. 1999; Reitmayr & Schmalstieg 2004), there are not enough qualitative nor quantitative studies in the Human and Computer Interaction (HCI) field, and studies in which geographic information is involved are especially few. Finally, in terms of improving the user interface in the AR view, I would like to add extra information such as distance, which could help to reduce navigation errors, moving forward with an effective AR navigation system that works seamlessly from outdoors to indoors.

References


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