RFID Based 3D Indoor Navigation System Integrated with Smartphones

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Abstract. Nowadays there are a lot of high rise, complex and huge buildings in the cities especially in metropolises. These building are almost like a small city with their tens of floors, hundreds of corridors and rooms and passages. Sometimes people lost their way in these huge buildings. Due to size and complexity of these buildings, people need guidance to find their way to the destination in these buildings. In this study, a mobile application is developed to visualize pedestrian's indoor position as 3D in their smartphone and RFID Technology is used to detect the position of pedestrian. While the pedestrian is walking on his/her way on the route, smartphone will guide the pedestrian by displaying the photos of indoor environment on the route. Along the tour, an RFID (Radio-Frequency Identification) device is integrated to the system. The pedestrian will carry the RFID device during his/her tour in the building. The RFID device will send the position data to the server directly in every three seconds periodically. On the other side, the pedestrian will just select the destination point in the mobile application on smartphone and sent the destination point to the server. The shortest path from the pedestrian position to the destination point is found out by the script on the server. This script also sends the environment photo of the first node on the acquired shortest path to the client as an indoor navigation module.

Keywords. Indoor Navigation, Smartphone, Android, RFID, Mobil

1. Introduction

Nowadays there are a lot of high rise, complex and huge buildings in the cities especially in metropolises. These building are almost like a small city with their tens of floors, hundreds of corridors and rooms and passages.

Sometimes people lost their way in these huge buildings. Due to size and complexity of these buildings, people need guidance to find their way to the destination in these buildings. Although there are a lot of studies about indoor navigation on 2D (two dimensional) maps, pedestrians need more realistic navigation system that routes pedestrians in buildings as 3D (three dimensional) (Musliman et al., 2009).

In this study, a mobile application is developed to visualize pedestrian's indoor position as 3D in their smartphone. User will select the destination point on smartphone. Indoor positioning of the pedestrian will be supplied by the RFID mobile device which the pedestrian holds during his/her tour. This mobile application uses client server architecture, the client side is represented by smartphone and RFID mobile device. The server side is represented by a web server, which holds a spatial database. Within the scope of this study, indoor environment is taken photo in three-meter intervals between all nodes and photo-frame library is established. Every photo is processed separately to decrease the storage size without losing much image quality due to making data transfer faster. The spatial database is designed by relating the nodes on 3D node networks with the photo frame library. Thus, this keeps the database information of photo frame library belonging to the indoor points. Client (smartphone) connects to the web server on a wireless network connection and sends user defined route to the server. When the route information arrives to the server, a web service is activated to query database. The query is retrieving operation of photos on the route from photo frame library. The result of the query consisting of a group of photos is sent back to application on the smartphone using the wireless network connection. While the pedestrian is walking on his/her way on the route, smartphone will guide the pedestrian by displaying the photos of indoor environment on the route.

There are many technologies and systems proposed for indoor positioning. RFID technology is a step ahead from other current technologies in terms of accuracy and other advantages. Today, there are some RFID readers and tags which are plug and play on smartphones. These portable RFID readers and tags which can be easily found in market are not widespread because of some disadvantages such as short read ranges, causing mobile devices run out of charge quickly and making attached mobile device grow in size. Beside, with the advancement of technology it is expected that RFID readers and tags are placed inside mobile devices in production just like integrated WIFI adapters and this advancement will provide a more effective use of RFID in the near future. Hence, mobile phones will be able to use RFID based indoor positioning systems and serve various personalized services.

2. Proposed RFID Based Positioning System for Indoor

2.1. RFID Technology

RFID is a term used to define wireless non-contact use of radio frequency electromagnetic fields to transfer identification data of an object for the purposes of identifying and tracking (Khong and White 2005). The data is stored in tags which is an electronic data storage device (Transponder tag) like smart cards. On the other hand, unlike smart card systems the power needed for both tags and transferring data between reader and tag is provided by use of non-contact electromagnetic field. A reader is required to receive data from a tag (Finkenzeller 2003). A reader loads energy to its antenna in order to make it transmit radio signals for activating tags and receiving data from tags. An activated tag transmits its data (Khong and White 2005). The antenna provides communication between reader and tag and some properties differ such as frequency range which affects the performance of the system depending on the shape and size of the antenna (Dziadak et al. 2009).

RFID tags can be either active or passive according to the power source. An active tag has its own power source generally obtained from a battery and this kind of tag transmits its ID periodically. A passive tag gets its power from the signal of the reader (Manish and Shahram 2005).

Two fundamental components of an RFID system are reader and tag. Beside this, antennas, computers and database systems are used in order to make system more effective. Components of an RFID system are shown in Figure 1. Another important issue is the frequency range of the reader. Available frequencies are LF (Low Frequency), HF (High Frequency) and UHF (Ultra High Frequency) (L. Wang et al. 2007). In addition, frequency ranges such as SHF (Super High frequency) or microwave can be used.

2.2. Developed Software

In the study, a software for the mobile RFID devices has also been developed. Geographical proximity approach has been used in this program. In every two seconds, RFID reader receives data from the tags within the reading range. Receiving data period also can be set by the user in "Configuration" tab (Figure 1).

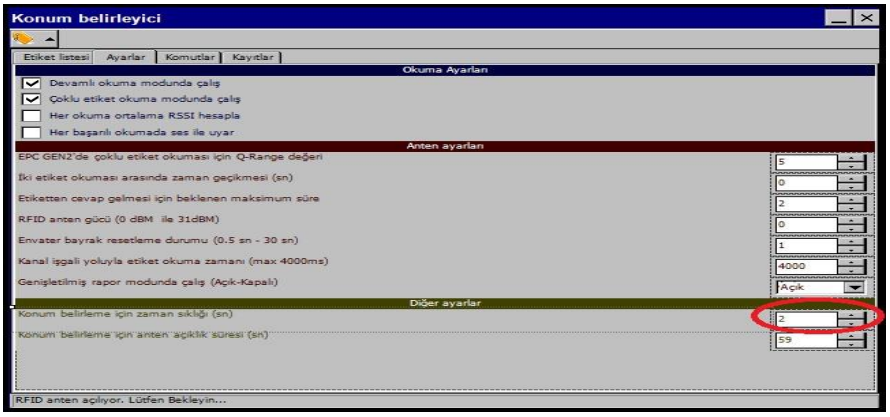

Figure 1. Configuration (Ayarlar) Tab.

At the end of every period, the tag which has the strongest signal is determined by the software based on collected data. Then the predefined coordinates of this tag are sent to the user. The software has been tested in three different design models as mentioned above.

3. Mobile Application

The application is aimed at Android Mobile Operating System that has a widespread user and developer groups on the world (Dimarzio, 2008). Since the Android Application is generally developed based on Java programming language, Eclipse Interactive Development Environment (IDE) is used as a development environment. This mobile application is coded to able be run on all versions of Android from Android 2.2 (API Level 8) to Android 4.4 (API Level 19) http://developer.android.com. Script on the web server to query on the database is coded in PHP (Hypertext Preprocessor) web based programming language. Oracle Database 11g Database is used on the web server as database management system to keep all information (nodes, links, the paths of photos, extra definition about points and so forth) about the mobile application. The results of query on the server is formatted as JSON (JavaScript Object Notation) to make a lightweight data transfer from the server to the smartphone www.json.org.

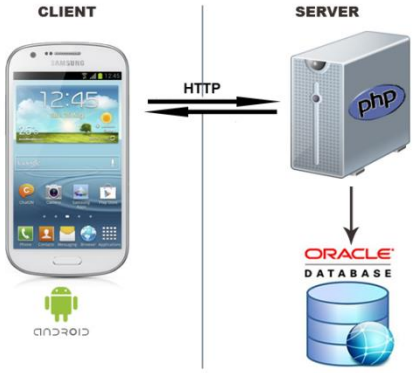

Figure 6. Architecture of the mobile application.

This study is realized in three basic steps. In the first step, the database of the application is designed and provided a sample indoor environment's data. In the second step, the Android mobile application that works on client (smartphone) is developed. At the last step, a web based script is coded to connect to the database and to retrieve the photos on the route of pedestrian from the database on the server.

3.1. Database Design

In the database design, two different tables that are related to each others are created. The first table (link table) keeps the information of links between nodes in the building. In this table, every link has a specific identification number, a different start node and a different end node. The second table (photo table) keeps the name of the environment photo that belongs to each point in every link in the building. The second table also keeps extra information to specify the location of every points in the links. Therefore, every link in the first table has at least two related records (points) in the second table. The number of records that belongs to a link is calculated by considering the link length. If the link length is longer than three meters, then the link has more than two records in the second table for the reason that the indoor environment is taken photo in three-meter intervals between all nodes as mentioned before.

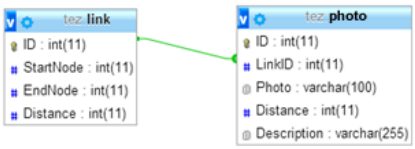

Figure 7. ER diagram of spatial database.

3.2. Development of Mobile Application

In the development of mobile application step, a graphical user interface is designed for pedestrian on the smartphone. There is a drop down boxes for selecting the destination node and an OK button on the screen. The pedestrian clicks on the OK button just before he/she starts the tour. Then the RFID mobile device sends the position data of the pedestrian as the departure node to the server. The application connects to the server by using http protocol. The script on the server runs and sends the related indoor environmental photos back to the smartphone. Thus, the indoor photos will be loaded to the smartphone according to the position data supplied by RFID device. Therefore, every point in the pedestrian's route will be displayed on the smartphone.

Figure 8. Mobile Application.

3.3. Development of Web Script

In the last step of the study, a PHP script is developed running on an Apache web server. The script takes the departure and destination node as argument coming from Android application. The script finds the shortest path between departure and destination. Thus, the script reveals the links on the pedestrian's route and navigate the pedestrian according to the defined route. The script also sends the photo of indoor environment according to the position data supplied by RFID device. The navigation data and environmental photo is sent back to the client as JSON format useing http protocol.

4. Conclusion

In this study, an RFID based indoor positioning system has been introduced. An RFID (Radio-Frequency Identification) device was integrated to the indoor navigation system for smartphones. The pedestrian need to carry an RFID device during his/her tour in the building. RFID device is used to determine the exact position of the pedestrian in indoor environments whose all floors, corridors, passages and rooms are equipped with RFID tags. The RFID device, handed by the pedestrian, reads the tags and find out pedestrian's 3D position in the building. The RFID device will send this position data to the server directly in every two seconds periodically. As soon as the script on the server gets the position data from RFID device and destination points from the smartphone, then it finds out the shortest path from departure point of the pedestrian to the destination point. The script sends visual navigation information to the client to inform the pedestrian on his/her way.

The success of the mobile RFID device in estimating positions is 76%. In the case that position estimation error has been considered ± 1 meter, 87 measurements out of 90 which approximately correspond to 97% of total has provided the criteria. In the worst case, position estimation error has been obtained 2 meters. In 3 measurements out of 90 which approximately correspond to 3% of total, position estimation error has been observed 2 meters.

Each indoor environmental photos could be loaded to the smartphone in two seconds by the script on the server via WiFi internet connection. So the pedestrian will get a real-time working indoor navigation system that is running on smartphone.

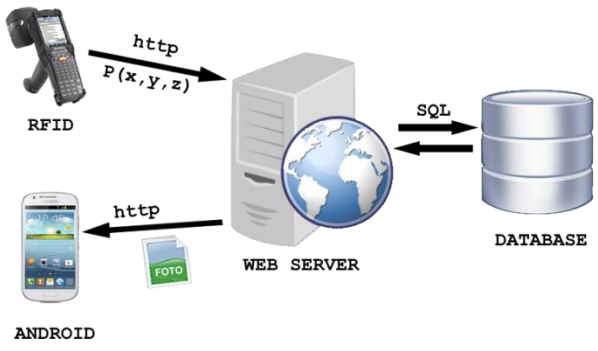

Figure 9. RFID device integrated navigation module.

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