3D Indoor Navigation Prototype For Smartphones

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Abstract Nowadays, there are a lot of multi-storey, complex and huge buildings in the cities especially in metropolises. These buildings 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 the 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 has been developed to visualize a pedestrian's indoor location as 3D in his/her smartphone. This mobile application has the characteristics of a prototype for indoor navigation systems. While the pedestrian is walking on his/her way, the smartphone will guide the pedestrian with the photos of indoor environment on the route, arrow marks and text information. As a future plan, an RFID (Radio-Frequency Identification) technology can be integrated to the system to detect the location of the pedestrian during his/her tour in the building. By this way, the system will navigate the users more accurately as a real-time navigation system.

Keywords: Indoor Navigation, Smartphone, Android, RFID

1 Introduction

GPS (Global Positioning System) has an extensive usage in outdoor areas for navigation. However, GPS cannot be used in indoor areas properly due to the weakness of its signals in the buildings. Nowadays, the dimensions of the buildings and the indoor environments are enlarged extremely. Therefore, it is difficult to find the way in these types of buildings due to the size and the complexity. For instance, when people visit multi-storey and complex buildings such as trade centers, shopping malls, skyscrapers, airports, hospitals and universities, they need a navigation system to find their way to the destination . Although there are a lot of studies about indoor navigation on 2D maps, pedestrians need more realistic navigation system that routes pedestrians in buildings as 3D (Musliman et al. 2009).

In this study, an indoor navigation system for smartphones is developed to visualize the pedestrians' locations in the building as 3D in their smartphones. This mobile application has the characteristics of a prototype for indoor navigation systems. It uses client server architecture, the client side is represented by smartphone and server side is represented by a web server which holds a spatial database. In the application, a user only selects the current location and destination to start the navigation. Then, the navigation system finds the shortest path and guides the user in the building. Within the scope of this study, some specific indoor areas are called nodes. The distance between nodes can differ. Indoor environments between all nodes are taken photo in four-meters intervals. A photo-frame library is established with these indoor photos. The spatial database in the server relates the each photo in the photo frame library to the nodes on the building networks. Thus, a link is established between a specific indoor environment and its photo. Client (smartphone) connects to the server on a wireless network connection and sends the data of client's current location and destination. When the location information arrives to the server, a web service is activated to find the shortest path from thecurrent location to the destination. This web service finds the photos on the path and their spatial descriptions. They are sent back to the application on the smartphone using the wireless network connection again. While the pedestrian is walking on his/her way on the route, the smartphone will guide the pedestrian by displaying the photos of the indoor environment on the route and giving some extra information.

The paper is organized as follows. Section 2 referred some other indoor navigation system studies in the literature. Android mobile operating system is described in Section 3. Section 4 details the design of our proposed indoor navigation system for smartphone. The conclusion and the future plan are mentioned in Section 5 and 6, respectively.

2 Background

Candy (2007) developed an indoor location based GIS application that works on a GIS web server for mobile phones. The application creates a web page displaying floor plan of the building and draws a route line that users must follow. The users can connect to this web page via an HTML-supported mobile phone. The mobile phone must have RFID technology to determine user's location. The loaded web page to the mobile phone for navigation is a graphical interactive map. One of the disadvantage of the system is that the map of the floor plan must be loaded as a whole since the map is displayed in the HTML browser. Besides, there are some other difficulties like using HTML browser on a small screen size phone.

Hammadi et al. (2012) introduced an Android based 2D indoor navigation system to guide the visitors inside the widespread buildings in their study. The system utilizes the NFC (Near Field Communication) to detect the location of users. According to their system, the location of user is detected with NFC tags. User must specify a destination point to start the navigation. The disadvantage of the system is lack of the interaction between the system and the user along the navigation process and the system has a poor visualization service. Another shortcoming of the system, the user must make the smartphone scan the NFC tag to detect his/her location since it does not detect the location of user automatically.

Cheung et al. (2006) described a Bluetooth-based indoor positioning system. They used stationary beacons and a Bluetooth-enabled mobile device. The system can detect the location at the scale of 2-3 meters areas, only capture movement trajectories of people in the building.

Pritt (2013) proposed an indoor location system for smartphones and tablets that make use of commonly available Wi-Fi networks. The proposed location system needs a calibration stage before the usage for the navigation. The user can track himself/herself in the floor plan displayed on the mobile device as 2D. The success rate of his location system is 97.5% in a suburban home and 100% in a shopping mall. However, the success rate can differ from device to device, since mobile devices have different sensitivities to Wi-Fi signals. Besides a real-time navigation module can be added to this system.

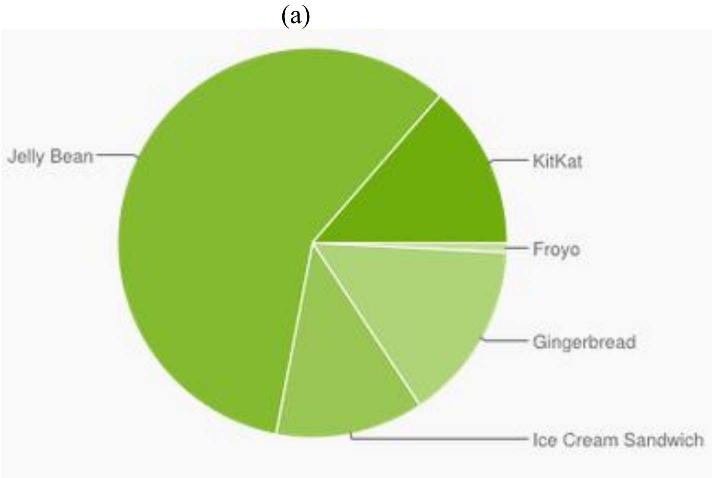
3 Android

Android is an open source, mobile device and smartphone oriented mobile operating system developed by Google and Open Handset Alliance. Android mobile operating system is established upon Linux 2.6 kernel (Dimarzio 2008). Android has an extensive user group on the world. Android mobile devices are used by millions of people more than 190 countries all over the world. The number of Android applications, downloaded from Google Play, is over 1.5 billion. Google Play is the official Android application store managed by Google. Android is one of the most rapidly-developing mobile operating system with its huge user group and new specifications.

Android presents a lot of advantages to the developers as well as it presents to the users. Developers can publish their applications on Android devices to make the applications accessible by the millions of Android device users. Android is not only a mobile operating system, it is also a Software Development Kit (SDK) with its API (Application Program Interface) libraries, developer tools to build, test and debug applications. Developers can test their applications on the emulators supplied by Android SDK. The user interfaces in the applications can be designed using XML. Android provides a lot of facilities to the developers with its flexible structure. Android platforms and their usage rate is shown in Fig 1. Our proposed indoor navigation system can run on all of these Android platforms.

Version	Codename	API	Distribution
2.2	Froyo	8	0.8%
2.3.3 - 2.3.7	Gingerbread	10	14.9%
4.0.3 - 4.0.4	Ice Cream Sandwich	15	12.3%
4.1.x	Jelly Bean	16	29.0%
4.2.x		17	19.1%
4.3		18	10.3%
4.4	KitKat	19	13.6%

(a)



(b)

Fig. 1 Usage rate of Android platforms (Android Developers, 4 June 2014)

Android offers opportunities of detecting the motion and the location with its location API. GPS (Global Positioning System) can be used to detect the location of Android devices. But generally, GPS is not sufficient for the indoor environment to detect the location.

4 System Design

Our navigation system has been carried out in three different steps. In the first step, the database of the navigation system was designed and this database was entered with a sample indoor environment data. Oracle Database 11g was preferred as a database management system due to its support of the spatial data (Atila et al 2013). The navigation system works according to client-server architecture. In the second step, smartphone application was developed as the client side application in the navigation system. The application was developed for smartphones and tablets that have Android operating system. Since the Android applications are generally developed based on Java programming language, Eclipse Interactive Development Environment is used as the development environment. In the third and last step, a script, which would work on server, was coded in PHP internet based programming language. This script takes arguments from Android application, finds the route for the users, transforms the route data (photos, location description) to JSON (JavaScript Object Notation) format and sends it back to the user via Android application. JSON was selected as a data transfer format since it is a lightweight data exchange format. Therefore, route data can be transferred from the server to the smartphone quickly.

The architecture of our navigation system is illustrated in Fig. 2 and these three steps of navigation system are detailed in the following parts.

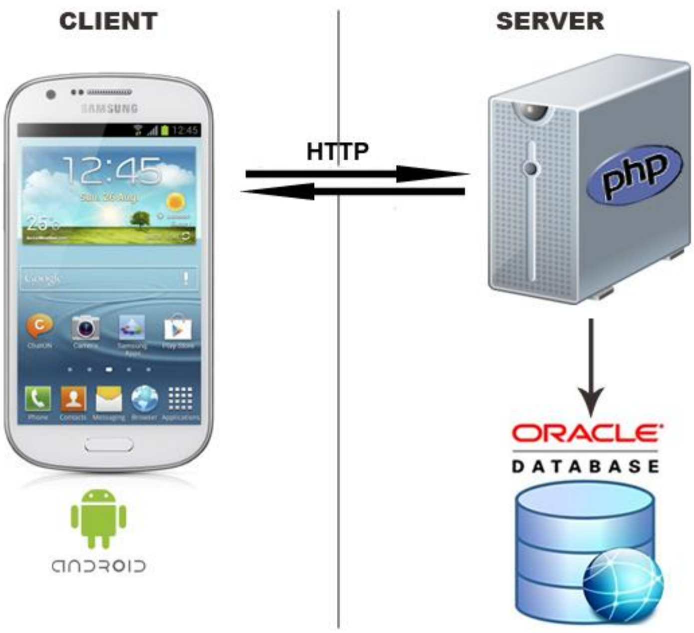


Fig. 2 Architecture of the navigation system

In the first step, a database called "tez" was created in Oracle Database 11g. The database has two tables related to one another. The first table, called "link", keeps the data of the links between the indoor nodes. The second table, called "sublink", is used for storing the indoor photos of each link. "link" table comprises of four fields called "ID", "StartNode", "EndNode" and "Distance", respectively. Each record in the "link" table keeps the link data between each node pairs and each record has a different ID number so "ID" field is the primary key of "link" table. In each record, "StartNode" field keeps the starting node of the link, "EndNode" keeps the end node of the link and "Distance" field keeps the distance of the links in meter. All of the fields in "link" table are integer. The following SQL code was used to create "link" table:

```
CREATE TABLE LINK(
    ID int not null auto_increment,
    StartNode int not null,
    EndNode int not null,
    Distance float,
    PRIMARY KEY (ID)
)
```

In Fig 3, the record with 32 ID number keeps the information of a 6 meters link between node 1 and node 2. Besides, the inverse of this link is kept as a different record with 38 ID number.

ID	StartNode	EndNode	Distance
32	1	2	6
33	1	3	8
34	2	3	5
35	2	4	10
36	3	4	5
37	3	5	7
38	2	1	6

Fig 3. "Link" table

Another table, "sublink", keeps some information such as the spatial description, the indoor photos and the distance of each point, which has four-meters interval to one another, on the links. "sublink" table comprises of five fields called "ID", "LinkID", "Photo", "Distance" and "Description" respectively. "ID", "LinkID", "Distance" fields are integer and "Photo" and "Description" fields are varchar (a type of string definition). "ID" field is primary key and each indoor photo is kept in the separate records in the "sublink" table. "Photo " field keeps the address path of related picture in the server. "Description" field keeps the spatial description of the indoor environment for each photo. "Distance" field keeps the interval between related point and the starting point of link. "LinkID" field matches the points to the link in the "link" table. Therefore, "LinkID" field indicates which point belongs to which link. Besides, "LinkID" field is foreign key of the "sub-link" table and supplies the conjunction between "link" and "sublink" table (Fig. 4). The following SQL code was used for creating "sublink" table:

```
CREATE TABLE SUBLINK(
    ID int not null auto_increment,
    LinkID int not null,
    photo varchar(255) not null,
    Distance int,
    Description varchar(255) not null,
    PRIMARY KEY (ID),
    CONSTRAINT fk_SubLink FOREIGN KEY (LinkID)REFERENCES Link(ID)
)
```

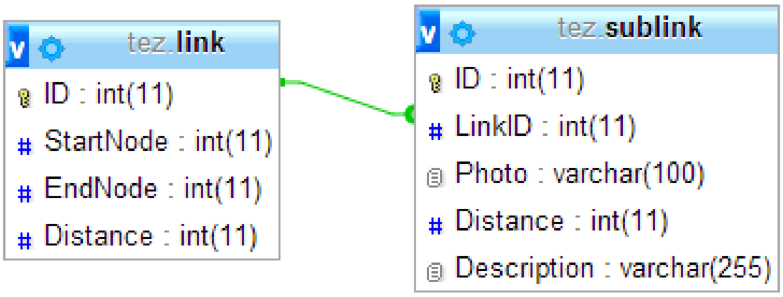


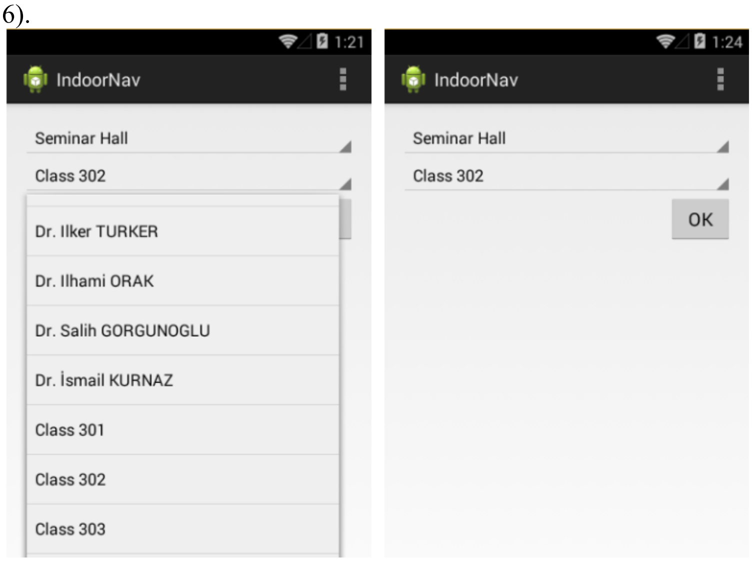
Fig 4. ER diagram of "tez" database

In this study, the environment photos among connected node pairs are taken in each four meters. These photos are stored in the "sublink" table in the separate records. In Fig. 5, 33 "ID" numbered record in "link" table connects node 1 and node 3 and the link has a distance of eight meters. The photos of the environment at 0^{th},4^{th} and 8^{th} meters of this link are taken respectively. Each photo is added in to the "sublink" table as a separate record with environmental description and distance to the starting node information of the point. The number of record in the "sublink" table belongs to a specific link in the "link" table differs according to the link length. For example, the length of the 33 ID-numbered link is 8 meters, so there are three records in "sublink" table for this link. These three records keep the information of the points at 0^{th} meter, 4^{th} meter and 8^{th} meter of the link, respectively.

ID	LinkID	Photo	Distance	Description
1	32	p120	0	Class 301
2	32	p121	4	Seminer Hall
3	32	p122	6	The chief of Comp. Eng. Dep.
4	33	p130	0	The chief of Ind. Eng. Dep.
5	33	p131	4	WC
6	33	p132	8	Lect. Yasin ORTAKCI
7	34	p230	0	Dr. Ismail Rakip KARAS
8	34	p231	4	Dr.Ismail KURNAZ
9	34	p232	5	Dr. Salih GORGUNOGLU

Fig 5. "sublink" table

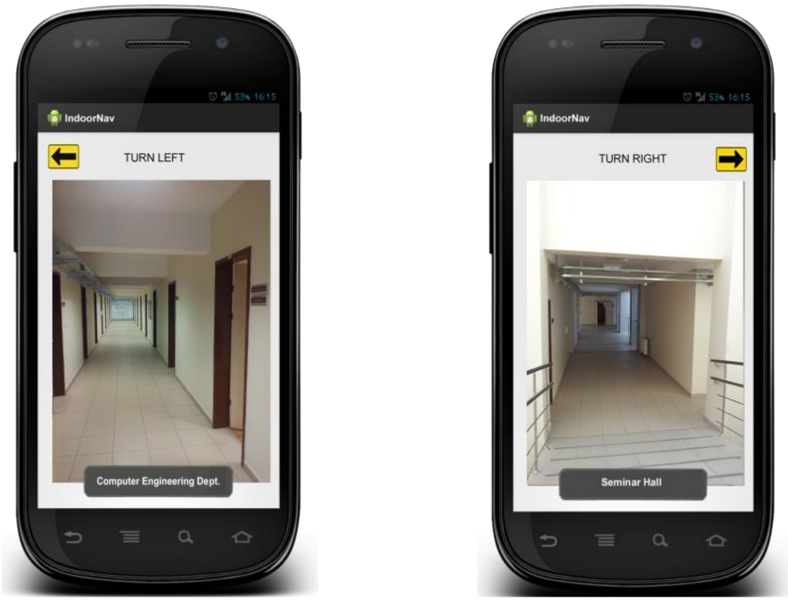
In the second step of the implementation, an Android application was developed for smartphones to supply interaction between the user and the navigation system. This mobile application has two different activity called Intro.java and Navigation.java, respectively. In Intro activity, user enters his/her current location and then selects the destination point. The graphical user interface of Intro activity has a dropdown list to select current location, a dropdown list to select the destination and an OK button to send this data to navigation module on the server (Fig. 6).



(a) (b)

Fig. 6 Intro activity screenshots

In the graphical user interface of Navigation activity (Fig. 7), there is a text view tool at the upper side of the screen to direct the users with text information. Besides, there are arrow marks on the screen to illustrate navigation instruction. There is an image view tool in the middle of the screen. This image view is used to display the indoor photos. The photos are provided from "Photo" field in the "sublink" table. A pop up message box, which describes the indoor environment, appears at the bottom of the screen while the indoor photo is being loaded. Content of pop up message is provided from "Description" field in "sublink" table.



(a) (b)

Fig. 7 Navigation activity screenshots

User's current location and the destination data are sent to the server script using HTTP protocols and IP numbers of the server. The script finds the shortest path between the starting point and the destination and sends the navigation data to Navigation activity on the smartphone. The navigation data includes a group of photos and their spatial descriptions. The navigation data may not be retrieved from server instantly because of insufficient internet connection speed in the wireless networks. Thus, AsyncTask class was used not to make wait users on the blank screen along retrieving the data from the server. AsyncTask class is an Android library class that welcomes user with a loading message while the navigation data is being loaded at the background.

In the third step of the implementation, a PHP script, working on a Apache web server, called "getData.php" was developed. First, the script connects to the "tez" database locally and finds the shortest path to the destination. The shortest path includes a group of nodes which will be visited in order. The links are found from "link" table by checking the start and the end node pairs on the path. Then, the photos and their spatial descriptions are retrieved from "sublink" table according to their LinkIDs and they are transformed to JSON format before being sent to Android application. An example JSON data is given below:


```
{"post":
   [
       {"description":"Class 301","photo":"p120"},
       {"description":"Seminer Hall","photo":"p121"},
       {"description":"Chief of Department","photo":"p122"},
       {"description":"Dr. Ismail Rakip KARAS","photo":"p230"},
       {"description":"Class 311","photo":"p231"},
       {"description":"Stairs","photo":"p232"},
       {"description":"WC","photo":"p310"},
       {"description":"Class 211","photo":"p311"},
       {"description":"Class 213","photo":"p312"}
   ],
   "success":1,
   "message":"Path is found successfully"
}
```


6 Conclusions

In the content of this study, The Outbuilding of Engineering Faculty in Karabuk University was selected as an application area. The photos of indoor environments of this building were taken each four meters. The size of photos was reduced in order to be processed efficiently. Then a photo-frame library is established on the server with these photos. The "photo" field of "sublink" table keeps the path of the photos in the library.

Our smartphone oriented navigation system worked successfully in the Outbuilding of Engineering Faculty. First, user connects to the internet on the Wi-Fi internet connection in the building and selects his/her current location and the destination in the application on the smartphone. Then navigation system finds the shortest path including the indoor nodes and points. Then it downloads the indoor photos on the path to the smartphone. Each photo is displayed on the screen in each four seconds. It is assumed for a pedestrian to walk four meters distance in a four-second time period. Using JSON format make data stream of photos quicker. Thus, user will not have to wait for the photos to be loaded to the screen of the smartphone while he/she was walking in his/her way.

The results show our prototype application can be a useful navigation tool for everyone who has a smartphone in the complex, multi-storey and huge building.

7 Future Plan

In this study, the user selects a starting node and a destination node and then runs the application just before starting to walk to the destination. Along the user's walk in the building, navigation system does not detect the location of the user automatically. Therefore it assumes that a pedestrian can walk four-meters distance in a four-seconds time period, and loads the photos of the points on the shortest path orderly in each four seconds. If the user does not obey the navigation instructions of the system and wander from the system-defined route, our application loses the control and cannot create a new route for user.

To overcome this disadvantage, an RFID based location determination technology can be integrated to the navigation system. The indoor environment of the building is equipped with the RFID tags in each point and the user handles an RFID reader. While the user is walking, the RFID reader will read the closest RFID tag and detect the location of the user as 3D (x, y, z) coordinates.

Another step in the location determination is to send 3D coordinate to the navigation system. This process can be handled in three different ways. First option, the RFID reader connects to the smart phone with Wi-Fi peer to peer connection. Second option, the RFID reader connects to the smart phone with Bluetooth connection. 3D user coordinate is sent to the server via smart phone in both ways. Third option, the RFID reader connects to the server directly and sends the coordinate to the system. All of these options can be feasible in our navigation system.

As a result, the location of users can be determined automatically adding the RFID technology to our navigation system. Thus, the navigation will work exactly real time. Even if the user does not obey navigation instructions and wander from the system-defined route, the RFID reader will detect the new location and produce a new route for the users. The users can easily find their way in the building without the need for any guidance. By this way, our navigation system can be applicable for all types of indoor navigation systems, even in emergencies such as earthquakes, fires etc. Furthermore, adding voice navigation to the system will increase usability.

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