Abstract—Indoor guidance is becoming a significant issue with the increasing number of buildings. This paper describes an Android based indoor map guidance system that assists and guides visitors inside public buildings (e.g. schools, shopping malls, airports, museums, exhibition centers). It utilizes NFC (Near Field Communication) technology and QR (Quick Response) Codes, which are low cost, to determine the location as well as to provide navigation within the buildings. Also, it provides a variety of helpful features such as finding destination, calculating shortest path, storing car parking location, giving feedback to building management, entering surveys for restaurants and coffee shops, finding nearest toilet and making donation. In addition, the system is bilingual and available in both English and Arabic versions. The developed system relies on a server that contains its web server, map server and spatial database. For wide accessibility, the whole system is developed using open source and freely-available software. For example, (a) the Android SDK is used to develop the client interface; (b) the Apache server is used for the web server; (c) Google sketchup and Quantum GIS are used to draw the floor plans; (d) PostgreSQL/PostGIS is used for spatial database to store the drawn floor plans; and (e) MapServer (MS4W) is used for map server to retrieve and draw the stored floor plans from the spatial database. Thus far, the developed mobile application has been fully evaluated and validated for use in a smart campus environment, which has been encapsulated in a test case study delineated herein.

Keywords: indoor navigation; iCampus; smartphones; Dijkstra; NFC; QR Codes

I. INTRODUCTION

Nowadays, with the rising number of buildings (e.g. schools, shopping malls, airports), it has become difficult for the day-to-day visitors to remember the interior map of each of these places accurately. There may be an information helpdesk that could provide guidance, but some buildings may not have such facility or the helpdesk is not close-by and cannot be readily located. Moreover, the visitor may further lose his/her direction inside the building, while trying to find the nearest helpdesk or map guidance (which itself is a very time consuming task). It is hence more convenient and appropriate if the visitors could simply view the interior map of the building on their mobile phone, wherever and whenever it is needed.

Indoor localization is concerned with finding the location of a targeted object/place in indoor environment. Similarly, outdoor localization is related to obtaining the position of a targeted object/place, but in outdoor environment. There are different methods used in order to determine the location of a device (e.g. mobile phone) in outdoor environment. The most common used technology is Global Positioning System (GPS). This technology is based on the satellite positioning system, and line of sight of the signal is required. It has a good accuracy in open space environment, but unfortunately it does not work well in an indoor environment due to the absence of line of sight of the satellites’ signals. Much effort has thus been conducted in order to overcome this problem. For instance, with the use of Assisted-GPS (A-GPS) where a data server with reference receiver is employed in order to assist the signals of the GPS – but the drawback with this solution is that it is not very accurate [1].

However, there are several other technologies used for indoor localization that vary in cost of implementation and accuracy. One of the approaches is to use Bluetooth, which is a short range communication technology. It has a good accuracy, but the cost of implementation is very high. Radio-Frequency Identification (RFID) is also another technology that could be used for indoor localization [2]. Position accuracy for RFID technology depends on the type of the tags, which is either active or passive, as well as the number of these tags. Existing RFID based indoor navigation solutions are generally based on the use of passive RFID tags [1] since active RFID are very expensive.

In addition, Wireless Fidelity (Wi-Fi) transmitters could be used for indoor localization. Nowadays, Wi-Fi transmitters are available in many buildings and this reduces the cost of implementation. Several Wi-Fi transmitters are needed in order to have an accurate localization result. Also, the network strength can vary and this could affect the accuracy of this technique [3]. Another solution is to use Ultra Wide Band (UWB) signals. This technology uses a wide bandwidth signal and could produce accurate results. However, it is not commonly used and the cost of implementation is high [4].

Alternatively, a low cost wireless technology with short range communication capability called Near Field Communication (NFC) [5] can be used for localization in indoor environment. NFC tags can be scattered throughout the building with known specified positions, so as to enable the ability in determining the location of a device that scans those tags. The accuracy in this case is guaranteed due to the fixed positions of the NFC tags.
Near Field Communication (NFC) is a wireless technology for short range communication. This technology has various applications such as payment, identification and sharing information. NFC operates in a frequency band of 13.56 MHz and supports various data transfer rates that can reach up to 424 Kbps. The setup time for communication in NFC is very small (less than 0.1 second). Also, it is used with a typical distance of less than 10 cm which is suitable for crowded places and safer in terms of its application.

A. Related Works

The authors in [1] have designed an indoor map guidance application that utilizes NFC technology in order to locate the users inside the building. The developed application is able to find the shortest path to selected destination, however, it does not provide other features and it only operates in phones that have NFC reading capability. On the other hand, the application proposed, in here, can work for both Android Smartphones [6] that have NFC reading capability and/or with the use of its in-built camera. Also, the proposed application can provide additional features such as its interactive functions with the users.

The Micello application [7] is an indoor map guidance application for Android and iOS platforms. It utilizes GPS to find user location outdoor and hence display available buildings nearby using Google maps. Also, it supports multi-level function. Comparing with the proposed indoor map guidance application, the users of Micello application need to manually select the start point and end point from the map, and then the path will be generated. However, the proposed application utilizes NFC technology and QR Codes to facilitate the process of finding its current location.

FastMall [8] is another indoor map guidance application that is designed for shopping malls and supports Android and iOS platforms. It also provides promotion offers inside the shopping malls, support multi-level buildings and can be operated offline. But the users need to pay in order to download some of the maps. In addition, it enables the user to store the car parking by recording audio message, unlike the proposed application that can store car parking information and subsequently calculate and draw the shortest path to it, based on its current location.

Moreover, the proposed application provides additional features that are not included in the above application. For example, it enables the users to fill surveys in order to evaluate a certain place inside the building. Also, it allows the users to make donation and choose between different donation options. In addition, it supports both the English and Arabic languages, and other languages can be added easily as well. Finally, the web based user interface enables the building management to view the result of the feedbacks readily, which separates the feedbacks based on the type, instead of receiving a huge number of diverse feedbacks in one email.

B. System Architecture

Fig. 1 illustrates the basic architecture design of the system. First of all, the map of the building should be laid-out and stored in a MapServer so as to be available to the users. The user, using the proposed system, can then read the URL of the map from one of the NFC tag inside the building. With that, the system will request the map from the server and download it to the mobile. The user can then view the downloaded map. In addition, he/she can perform different tasks such as finding the current location or navigating to a targeted destination. To facilitate this, the user would thus need to scan the nearest NFC tag inside the building.

![System Architecture](image)

C. Development Tools and Environment

The platforms that were used to develop the system are listed below:
- Google Sketchup is an open source sketching software. It has the capability of designing both 2D and 3D drawings. It will be used in this project to aid in drawing the floors plan of the building.
- Quantum GIS is an open source geographic information system. It has the capability of manipulating spatial data [9]. It will be used to add miscellaneous features to the floor plan such as the names of the rooms. Also, it will be used to design the route network (link-node model) with costs being specified as the lengths of the paths (in meters).
- PostgreSQL is an open source Object-Relational Database Management System (ORDBMS) for different platforms such as MS Windows. PostGIS is an extension for PostgreSQL database system that allows storing and manipulating spatial data. The floor plan details will be stored in this database system, which will be used as input to the MapServer [10].
- MS4W is a package that includes MapServer 6.0.1 for windows. It also contains other necessary tools such as Apache 2.2.19 Web Server and PHP 5.3.6.

II. System Design

The system can be decomposed into four main elements which are (a) the client interface, (b) the spatial database, (c) the web based user interface and (d) the server.

A. Client Interface

- View Map: this feature allows the user to view the map of the building. Also, it allows the user to
interact with the map such as panning, zooming and selecting specific place in the map in order to retrieve information about it. In addition, it enables the user to change between the maps of different floors (if exists). Moreover, it allows the user to determine his/her current location by scanning nearest NFC tag or QR Code, and then drawing the location on the map.

- **Place Information**: this feature allows the user to have more information about the building such as the building name, phone number, email address, website and other information. Also, it allows the user to use the provided information such as making a call, sending email and visiting the website.

- **Search**: this feature allows the user to search for destination inside the building. Also, it allows the user to view the search results and have more details about the destination such as phone number, email address, website and other details. In addition, it enables the user to find the shortest path to the selected destination.

- **Car Parking**: this feature allows the user to store the parking information by scanning a NFC tag or a QR Code that is placed on the door which leads to the parking area. The parking information is stored in SQLite Database in the application. Also, it allows the user to draw the path from the current location of the user to the door that leads to the parking area, as and when needed. Besides that, it also allows the user to delete the stored parking information.

- **Feedback**: this feature allows the user to give a feedback to the building management. It allows the user (a) to choose between different feedbacks types (e.g. comment, suggestion, compliment and complaint), (b) to fill the feedback details, (c) to provide optional information (e.g. name, phone number and email address) and finally (d) to submit the feedback.

- **Survey**: this feature allows the user to complete a particular customer/user survey that is customized for certain specific places inside the building such as restaurants and coffee shops. It allows the user to scan the NFC tag or QR Code of the survey in order to download the survey page from the server.

- **Nearest Toilet**: this feature allows user to find the nearest male/female toilet. It calculates and plots the path to the nearest available toilet based on its current location.

- **mDonation**: this feature allows the user to make a donation to, for instance, a specified entity or charitable organization, by scanning the NFC tag or QR Code of the donation. Upon scanning, it shows to the user the available donation options for them to select. It performs the donation via the SMS service with deduction being made via the mobile SIM card.

- **Favorite Places**: this feature allows the user to add the places, which he/she visits regularly, to the Favorites by scanning one of the NFC tags or QR Codes in the building and then storing this information in the SQLite Database of the application. Also, it allows the user to search and open the places in the Favorites or to delete them.

- **Preferences**: this feature allows the user to change the setting preferences of the system. It allows the user to change the language of the application to one of the supported languages (e.g. currently English and Arabic systems).

B. **Spatial Database**

- **Customized indoor map**: the database stores the indoor maps of the building as spatial data (e.g. points, lines and polygons). This data is used in order to draw the map when requested by the user.

- **Information about the building**: the database also contains information about the building and different places inside the building. The information is retrieved when requested by the user.

C. **Web Based User Interface**

- **View Feedback**: this feature enables the building management to view the submitted feedbacks from the users. Also, it allows them to reply to certain feedback if the user information (e.g. email address) is provided.

- **View Survey**: this feature enables the management (e.g. restaurant management) to view the result of the survey. It shows the results of the survey as statistics that are displayed in bars or tables. Also, it provides general suggestions on how to improve certain criteria (e.g. quality of food) pertaining to that particular facility.

D. **Server**

- **Retrieve Map from the database**: this function receives the request from the client and retrieves the required map from the spatial database. The map is generated by the MapServer using the spatial data that is retrieved from the database. Following that, the generated map is then downloaded to the client application.

- **Retrieve information from the database**: this function retrieves information from the database about the building or specific places inside the building when requested by the user.

- **Determine user location**: this function receives the location information based on the user’s scanning of the NFC tag or QR Code, and then use this information to determine the user’s current location and draws this location on the map.

- **Calculate shortest path**: this function receives the user’s current location and the desired destination, and then calculates the shortest path from the current location to the selected destination using Dijkstra algorithm [11]. Upon completion of the calculation, the shortest path is then drawn on the map to guide and navigate the user.
- **Store feedback**: this function receives the submitted feedback from the users and stores the results in the database.
- **Store survey**: this function receives the submitted surveys from the users and stores the results in the database.
- **Find nearest toilet**: this function receives the user current location and then calculates the paths to all male/female toilets and return the nearest toilet information to the user (based on its gender). Similarly, it will plot the calculated path on the map to the found toilet, in order to guide the user.

### III. Test Case Study

The aim of this test case study is to design and implement an indoor campus map navigation/guidance through NFC-Based Smartphones that will guide and assist the students or staffs, especially the new freshmen, within a smart campus environment. The system consists of several parts which are: client application operating in Android platform, spatial database that stores maps and information of the building and server that contains Web Server and MapServer to generate the maps. In addition, a web based user interface is implemented in order to help the management of the building to view the result of the feedbacks and surveys.

As mentioned before, the NFC and QR Codes are distributed in known and readily-accessible positions inside the building (see Fig. 2). Once the user runs the application, the main screen appears as shown in Fig. 3a. When the user enters the building for the first time, he/she is required to scan one of the NFC tags or QR Codes in order to download the information related to the building. In case the NFC reading capability is disabled/unavailable, a message will appear to inform the user and he/she can enable the NFC from the smartphone settings or to use the QR Codes capability. Upon scanning, the application will attempt to download the map information from the server using the URL read from the NFC/QR. After successfully downloading the information from the server, the main application feature is then displayed as shown in Fig. 3b, with the name of the building appears at the top of the menu.

When the user clicks on the “View Map” feature, the application will then request from the MapServer to generate the map and then display it to the user. In case the application could not connect to the server, an error message will then appear to request the user to try again. However, if the map is generated successfully, it will be displayed to the user with the name of the building and floor-level on the top of the map as illustrated in Fig. 4. With that, the user is able to interact with the map such as panning and zooming within the map itself. Also, the user can view the maps of the other floors by choosing the “change map” option from the menu, as shown in Fig. 4a. In addition, the user can find his/her current location by scanning the nearest NFC tag or QR Code. After scanning, the result is sent to the server to position and plot the user’s location on the map as shown in Fig. 4b. Apart from that, the user can also get more information about a specific place inside the building, for instance the details of a particular faculty office, by clicking on it as shown in Fig. 5a. Further relevant functions can then be provided to the user upon receiving the detailed information about that specific place. These functions include: “Calling”, “Sending emails”, “Visiting its website” and “Finding its shortest path”, with regards to that particular specific place, as shown in Fig. 5b.

The “Search” feature allows the user to search for a specific destination inside the building. When the user clicks on this feature from the application main features menu, the search activity interface appears, as shown in Fig. 6a. The user needs to enter the search phrase and then click on search button to perform the search. If there is a result for the search, it will be displayed to the user. With that, the user can then use the provided information to, for example, find the shortest path to that destination as shown in Fig. 6b.
application will ask the user to scan the nearest NFC tag or QR Code in order to determine his/her current location, as shown in Fig. 7a, so as to be able to calculate its shortest path to that destination. The server receives both the current location of the user and the desired destination to facilitate the shortest path calculation using the Dijkstra algorithm. Upon completion of the calculation, its evaluated path to the destination is then drawn on the map as shown in Fig. 6b. During the navigation process, the user can also choose to update or refresh his/her location by clicking the update location function from the menu and then scanning the nearest NFC tag or QR Code. If the user happens to scan the tag located at the destination, the application will inform the user that he/she has reached the destination. Once the destination is reached, the user can subsequently choose to cancel the navigation guidance.

Figure 5. Detailed information of the specified place

Figure 6. Destination keyword search and detailed displayed result

Figure 7. Shortest path from current location to desired destination

IV. CONCLUSION

This paper has detailed the designing of an indoor map guidance system via the use of portable mobile devices, with its case study set on a smart indoor campus environment. It is a mobile application for Android platform with NFC (Near Field Communication) and/or QR (Quick Response) Codes reading capability that allows the users to readily localize, navigate, and view the map of the building on their smartphone. The proposed system is also able to assist and guide visitors within any public buildings such as shopping malls, airports, hospitals, museums, exhibitions centers, etc. It utilizes modern technologies such as NFC technology and QR Codes in order to determine the current locations of the visitors. The NFC tags and QR Codes are distributed with known and in readily-accessible positions within the buildings; and the users of the system can then scan these tags to find their current location, and subsequently able to access the different navigation features inside the building. At the moment, the application is only able to provide the shortest path to a destination within the same floor only. As delineated in the paper, the system is designed and developed based on four main constitutional components which include the client interface, the spatial database, the web based user interface and the server.

REFERENCES