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I²Navi: An Indoor Interactive NFC Navigation System for Android Smartphones

Jing Hang Choo, Soon Nyean Cheong, Yee Lien Lee, and Sze Hou Teh

***Abstract*—**The advancement of smartphones, wireless networking and Near Field Communication (NFC) technology have opened up a new approach to indoor navigation. Although NFC technology has been used to support electronic commerce, access control, and ticketing, there is a lack of research work on building NFC-based indoor navigation system for smartphone users. This paper presents an indoor interactive navigation system (named I²Navi) based on NFC technology for users to navigate within a building with ease using their smartphones. The I²Navi system has been implemented at the Faculty of Engineering (FOE), Multimedia University (MMU) to enable students, parents, visitors who own NFC-enabled Android smartphones to navigate themselves within the faculty. An evaluation is carried out and the results show positive response to the proposed indoor navigation system using NFC and smartphone technologies.

***Keywords*—**Near Field Communication, indoor navigation system, smartphones.

I. Introduction

In recent years, rapid development in smartphone technology has expanded its functionality as a device for communication purposes to a small computer for various tasks such as checking emails, gaming, e-book reader and so on [10]. In addition, smartphones are also used as outdoor navigation devices via Location-Based Services (LBS), embedded Global Positioning System (GPS) receivers and navigation applications such as PAPAGO [11]. However, a GPS-based navigation system cannot function in an indoor environment because the GPS signal requires line-of-sight (LOS) and thus is not reachable in an enclosed environment.

This limitation has led to massive research in indoor navigation system through various technologies such as Wi-Fi [2], Bluetooth [3], FM [4], GSM [5], infrared [6], ultrasound [7], RFID [8] and ultra wideband (UWB) [9]. Each of these technologies has its own advantages and disadvantages. For example, UWB and Wi-Fi could provide higher accuracy in positioning compared to Bluetooth, but require higher implementation costs and more complex designs. This paper proposes a simple and cost-effective design for indoor navigation system, I²Navi, based on Near Field Communication (NFC) wireless communication technology running on Android-based smartphones. A customized navigation application was developed to help users navigate within the Faculty of Engineering, Multimedia University, through NFC-enabled smartphones and NFC tags. NFC tags were embedded in advertisement posters positioned at different locations within the building and user can determine their location by tapping on the designated posters.

The rest of the paper is organized as follows: A review of related work on existing GPS navigation systems, smartphones and NFC technologies is covered in Section II. The design of the proposed I²Navi system is presented in Section III whereas its implementation is covered in Section IV. The result of the initial evaluation of the I²Navi system is discussed in Section V. Finally, the paper is concluded, along with potential future work, in Section VI.

II. Related Work

A. GPS for Navigation

GPS is used in a wide range of applications especially for land-based navigations [1]. Given the availability of relatively cheaper GPS receivers, navigation devices have become affordable and common. GPS works by calculating the user's location by triangulation using signals transmitted by at least three satellites within LOS [12]. This requirement causes two issues for users. First is the time taken to obtain the position of receiver [2] (time to first fix), where the user needs to wait for the GPS signals. In some locations, such as urban cities with many tall buildings surrounding, it may require more than one minute [12]. A-GPS (Assisted GPS) can reduce some of this delay. However, the root problem remains, as GPS availability [12] is limited. Furthermore, GPS signal is not accessible in indoor environment. The second issue is that as the time to first fix is longer, the more power [12] will be consumed. This is a disadvantage for battery-powered devices like smartphones. In addition, according to S. Gaonkar et al., the high battery consumption of GPS receivers can affect the battery's lifetime [13]. The reduction in the size of the GPS receivers and the integration of GPS systems with smartphones bring a lot of benefits to users, but these two main issues need to be resolved for indoor navigation system.

B. Smartphone and NFC

A smartphone, in the context of this paper, is defined as the hand phone using operating system such as Android[1], iOS[2], RIM BlackBerry[3] and Windows Mobile[4]. Google Nexus S[5] is the first Android smartphone with Near Field Communication

J.H. Choo (jinchoo.mescorp@gmail.com), S.N. Cheong (sncheong@mmu.edu.my), Y.L. Lee (yllee@mmu.edu.my) and S.H. Teh (tehszehou@gmail.com) are with Faculty of Engineering, Multimedia University, Cyberjaya, Malaysia.

[1] See http://www.android.com
[2] See http://www.apple.com/ios
[3] See http://www.rim.com/products/blackberry_os7.shtml
[4] See http://www.microsoft.com/windowsphone/en-us/default
[5] See http://www.nfcworld.com/nfc-phones-list

(NFC) support built in. NFC enables a smartphone to read or write data, perform card emulation and peer-to-peer contact. Although there is currently limited NFC-enabled smartphones in the market, its availability is expanding proportionally with new rollout of smartphones. Smartphones with embedded NFC chips enable users to save cost and space by utilizing a single device for increased functionality.

NFC is a short-range wireless communication technology that enables the exchange of data between devices at approximate 10cm distances. It operates at the frequency of 13.56 MHz in the unregulated radio-frequency (RF) band and offers data transmission speed of up to 424 kbits/s. NFC is the extension of the ISO 14443 proximity card standard which combines a smart card and a reader. Therefore, an NFC device is not limited to communicating with other NFC devices only, but also existing ISO 14443 smart cards and readers, thus making it compatible with the existing infrastructures like public transportation and payment terminals. The simplicity of NFC is very advantageous for consumers to perform transactions, exchange contacts and connect devices by placing the devices within close proximity of each other [14].

NFC has evolved from a combination of contactless, identification, and networking technologies. According to definitions in NFC forum, NFC has three operating modes: Peer-to-Peer, Reader/Writer, and Card Emulation. In the Card Emulation mode, data is transferred from NFC device to NFC reader [14]. This mode gives an advantage of eliminating the need for a physical payment medium, as mentioned by Ok et al. [15]. MasterCard PayPass[6], Google Wallet[7] and the upcoming ISIS Mobile Wallet[TM8] are some of the examples of services that eliminate the need for carrying credit cards, debit cards or cash. Another example is the electronic key application which eliminates the need for carrying bulky physical keys [15]. Isomursu et al. presented an attendance control system using the card emulation method [16]. The Peer-to-Peer mode is in which data exchange occurs between two NFC-compatible devices. According to K. Ok et al., applications such as exchanging business card and making new friends can occur within this mode [15]. NFC connects both devices in an instantaneous way which saves a lot of time. This mode is mostly used for device pairing. The last mode is the Reader/Writer mode, in which an NFC device can operate either in the active mode or passive mode. Active mode devices such as NFC readers and NFC-enabled smartphones generate a field to initiate the communication, so if a user has a NFC enabled smartphone on hand, he is not required to buy another NFC reader. On the other end are passive mode devices, such as the low cost NFC tag, which are unpowered and waiting for communication requests. Digital content can easily be embedded into the tag by using an NFC-enabled smartphone or an NFC writer. A common application is the smart poster. As an example, Miraz et al. implemented a smart poster system that allowed students to retrieve information on department and academic staff [17]. This mode provides advantage of mobility as users can bring the information with their phone to everywhere [15]. Also, this mode can be easily implemented as compared to other modes.

In a nutshell, NFC technology is affordable, simple to implement and provides time-efficient interaction. These benefits have opened up an opportunity to adopt NFC technology to achieve cost effective indoor navigation system.

III. System Design of the I^{2}NAVI

A. Hardware

The I^{2}NAVI uses NFC tags and an NFC enabled Android smartphone with the customized I^{2}NAVI navigation application to provide a cost effective indoor navigation system, as shown in Fig. 1. Each NFC tag has a unique identifier and is used to store location information such as coordinates which is used to search for a destination point within the system. The number of tags required depends on the size and intricacy of a building. For instance, buildings with many floors and wings will need more tags for a more effective navigation. These NFC tags can be embedded in existing advertisement posters with a marked dedicated space for users to access for direction (see Fig. 1). When activated, the I^{2}NAVI navigation application, installed on the Android NFC-enabled smartphone, will be able to read information such as the current location from the NFC tag and subsequently guide the user through a directed path on the floor plan via smartphone's screen to the intended destination.

Fig. 1 Hardware components of the I^{2}Navi

[6] See http://www.paypass.com/tap_and_go/index.html
[7] See http://www.google.com/wallet
[8] See http://www.paywithisis.com

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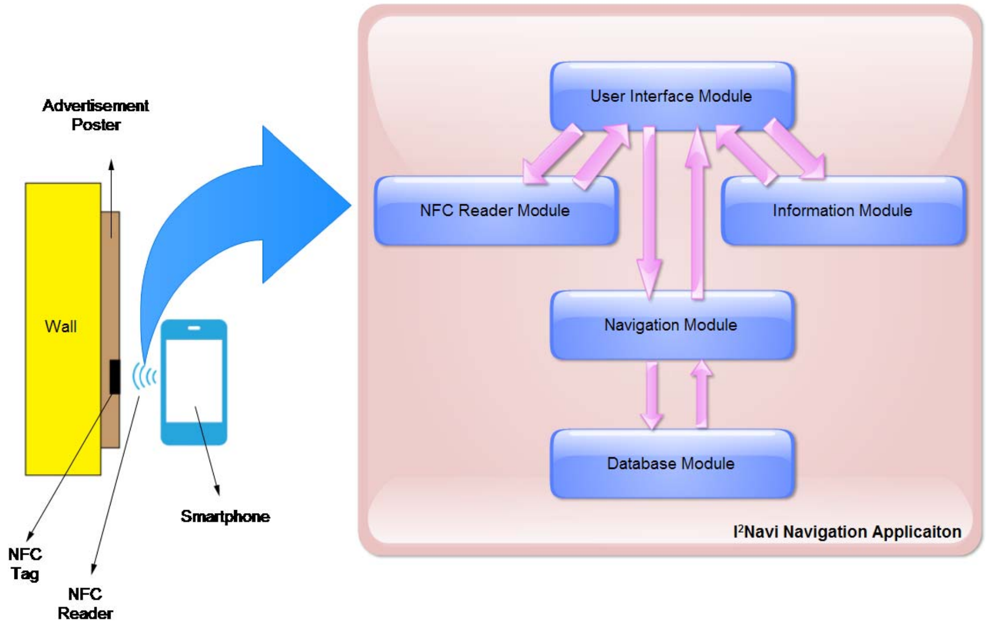

Fig. 2 Software components of the I^{2}Navi navigation application

B. Software

The key components of the proposed I^{2}Navi navigation application are illustrated in Fig. 2. It consists of the User Interface Module, NFC Reader Module, Navigation Module, Database Module and Information Module. The NFC Reader Module reads coordinate information from the NFC tag (embedded inside an advertisement poster) whenever the NFC-enabled smartphone (with the I^{2}Navi navigation application running), is positioned near to a tag. Once read, the coordinate information is sent to the User Interface Module and displayed on the smartphone's screen. Subsequently, the User Interface Module obtains the floor plan corresponding to the current coordinates from Information Module. A floor map with the current location marked is then displayed on the screen. If the user selects a destination through the user interface, the Information Module will provide more information such as (a) website(s) about the destination, if any. Apart from that, the Navigation Module is able to compute a suitable route and also provide directions to the destination by using information from the Database Module. The suggested navigation route is then displayed on the screen through the User Interface Module. Thus, a complete navigation with maps and a route from the current location to the destination is obtained.

IV. System Implementation of the I^{2}Navi

The I^{2}Navi system has been implemented at the FOE, MMU. Floor plans of the faculty such as laboratories, offices, tutorial and lecture rooms, staff rooms etc. have been integrated into the system with the aim to assist new students and visitors to locate desired destinations or explore the building through NFC-enabled smartphones. NXP Semiconductors NTAG203(F) and Samsung Galaxy SIII smartphones were used as read/write devices for the development of the NFC tags. A set of these NFC tags were then embedded in several existing advertisement/information posters. The NFC tags embedded posters were placed in various locations within the building. Each tag contains related location information.

Fig. 3 Implemented I^{2}Navi system

Fig. 3 shows a snapshot of the interaction between a user and the poster through the I^{2}Navi navigation application. Whenever there is a NFC-enabled advertisement poster sign,

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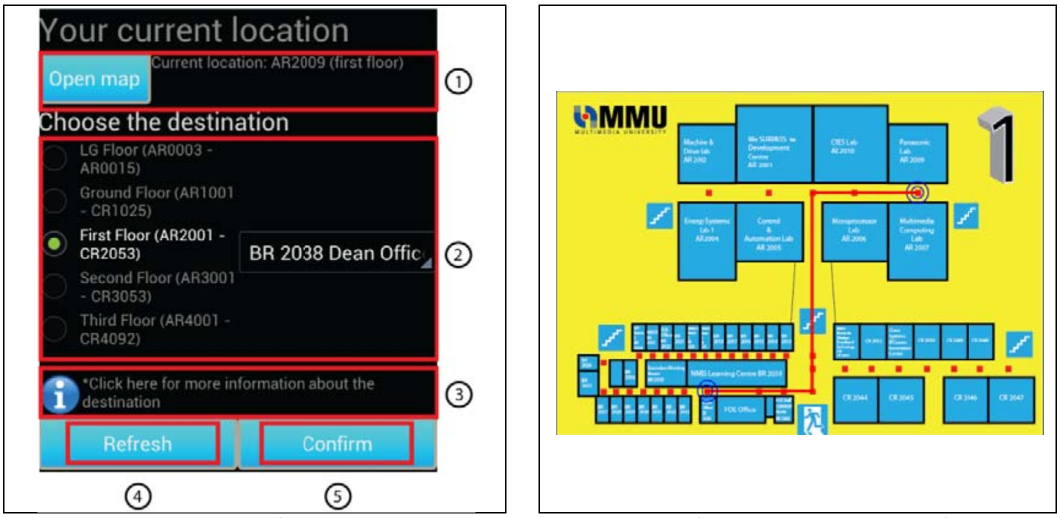

(a) Select destination interface (1) Open the map for current location. (2) Select a destination to be navigated. (3) More information about the chosen destination. (4) Refresh the choice for destination. (5) Confirm about the chosen destination.

(b) Example of navigation path in ground floor

Fig. 4 Implemented I^{2}Navi navigation application

users can determine their current location and identify the direction to a specific room within the building by tapping their smartphones on the poster. When an embedded NFC tag in the poster is within the read range of the NFC-enabled Android smartphone, the application is initiated (if it has not been previously initiated by the user). Fig. 4(a) shows the user interface. Once the application is instantiated, the view shows the user all the available options: (1) Browse map for current location, (2) Choose a destination to be navigated, (3) Obtain more information about the chosen destination, (4) Refresh the choice for destination, and (5) Navigate to destination.

The information received by the user during previous interactions with embedded NFC tag could be stored for viewing the map at the current location. For example, if the application detects that the current position is within the first floor, the floor plan or map associated with that level will be shown. The user could also reopen the map showing his original position even after the navigation to the destination is completed.

The system also allows the user, without the need of re-reading an NFC tag, to choose a different destination located within the building. During the search process, I^{2}Navi allows users to choose the destination based on two criteria: (a) selection of level (range of number of room is given) and (b) selection of room number. Once the destination is selected, the application will match the chosen coordinate with the corresponding floor plan map from the database.

When the user selects a destination, more information about the destination could be obtained by tapping on the “?” button. This feature enables the user to access detailed information about the destination through the related web pages.

Once the user confirms the selected destination, navigation starts on next screen (Fig. 4(b)). As the system does not use any other positioning technology for determining the current location of the user when the request is performed, the position of the last embedded NFC tag accessed by the user is considered the current location. It is marked in the generated map. Fig. 4(b) shows the resulting map and two circles that indicate the original and destination locations. As the user navigates along the path, he can tap the smarrphone with the running application onto reference tags (if any) to validate their route. If the path the users are on is incorrect, the application will generate a notification.

Fig. 4(a) and 4(b) also depict a simple scenario of using I^{2}Navi in FOE by a new student. According to the scenario, the user wants to be directed to the Dean’s office (BR2038), and starts navigating inside the building for this purpose. He touches to the first NFC tag within his view (AR2009) with his NFC-enabled Android smartphone. The location information on the tag is transferred to the application in his smartphone. He selects and confirms the desired destination (Fig. 4(a)). The application subsequently figures out a suitable route and shows it on the smartphone display (Fig. 4(b)). When the user arrives the destination (the Dean’s office), the application notifies the user that he has reached the destination.

V. Evaluation and Discussion

An evaluation of the I^{2}Navi system was conducted to obtain initial feedback for the proposed indoor navigation system in terms of user acceptance, usability and costing. A group of eight students were randomly chosen to participate in the evaluation. All the evaluators found that the directions provided were easy to follow and the application navigated them efficiently. By an effortless tap on a poster, the users can obtain their current location and simply follow the direction shown on the map. They agreed that this system potentially minimizes the chances of a person getting lost in unfamiliar environments. Most of the evaluators also agreed that the system is considered cost-effective because it only requires users to own an NFC-enabled smartphone in order to interact with the advertisement posters found within the building. However, some evaluators noted that the price of current NFC-enabled smartphones is relatively high and may be prohibitive, especially to those with lower purchasing power such as students, although the cost of deployment of the system on the whole is rather low.

VI. Conclusion

This paper presents a simple, low-cost, fast-responding and reliable indoor navigation solution by utilizing the NFC technology. The cost of this system is kept low with the use of relatively cheap passive NFC tags embedded in existing advertisement posters. In terms of response delay, the transfer of data from NFC tag to smartphone is "instantaneous", so users practically do not need to wait for the response. The tag provides accurate position and room information. The I^2Navi system was successfully implemented in Faculty of Engineering, MMU, to help new students and visitors locate offices, rooms and labs. An evaluation was conducted by a group of randomly chosen students and the results indicated that the proposed indoor navigation system is user-friendly and well-suited for the faculty. In the near future, more extensive evaluations will be carried out, involving larger groups of participants, to obtain more feedback for improvements on the system. In addition, the I^2Navi system will be extended to support the entire university.

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