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# Design and Development of NFC Smartphone Indoor Interactive Navigation System

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**Abstract:** The advancement of smartphones, wireless networking and Near Field Communication technologies have opened up a new solution to indoor navigation. Although Near Field Communication technology has been used to support electronic commerce, access control and ticketing, there is limited research work carried out on developing indoor navigation system using such technology. This paper presents the Indoor Interactive Navigation System for users to navigate within a building easily and conveniently through NFC-enabled smartphones. A prototype of $I^2$Navi has been implemented at the Faculty of Engineering, Multimedia University to guide students, parents and visitors in navigating the faculty easily. An evaluation of the system was conducted and the result is encouraging.

**Key words:** Near Field Communication · Indoor navigation system · Smartphone application

## INTRODUCTION

In recent years, due to the rapid development in its technologies, the smartphone expanded its functionality as a communication device to a mobile computer. It is now used for numerous daily activities, including accessing emails, gaming and reading e-books [1]. Besides serving as portable computer, smartphones are also commonly used as outdoor navigation devices through applications such as Waze[1] via Location-Based Services (LBS) [2], with built-in Global Positioning System (GPS) receivers. However, existing GPS-based navigation systems do not operate well in enclosed environments (indoor navigation) because GPS signals require a line-of-sight (LOS) transmission. Therefore, a GPS-based navigation system can lead a person to a place of interest such as a shopping mall, but will be unable to assist the user further within the mall, such as locating a particular store.

Smartphone technology can potentially enhance indoor navigation such as tracking a person's location and locating point of interest. This has led to massive research being carried out to achieve indoor navigation system through various technologies such as Wi-Fi [3], Bluetooth [4], FM [5], GSM [6], infrared [7], ultrasound [8], RFID [9] and ultra wideband (UWB) [10]. This paper presents an alternate solution to indoor navigation using Near Field Communication (NFC) and smartphone technologies. A prototype of the Indoor Interactive Navigation System ($I^2$Navi) was implemented to assist navigation within the Faculty of Engineering (FOE) building, Multimedia University (MMU), Malaysia. The system makes use of NFC tags embedded in posters positioned at various locations inside the building. These function as reference coordinates for users to use on an interactive floor plan on their NFC-enabled smartphones, for indoor navigation.

This paper is organized as follows:

Section 2 reviews related work on existing GPS navigation systems, smartphones and NFC technologies. Section 3 presents design of the $I^2$Navi system and Section 4 details implementation of the prototype. Section 5 presents evaluation results that demonstrate the feasibility of implementing the $I^2$Navi system. Conclusion and future work are included in Section 6.

**Related Work:**

- GPS receivers are getting smaller and more affordable and have, in recent years, been integrated into smartphones. This has enabled land-based navigation to be easily made available to users.

[1]Waze, Waze Ltd., Ra'anana, Israel

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Whenever three signal-transmitting satellites are within LOS of the GPS receiver [11], the device can determine its location through the triangulation method. However, the time it takes to obtain the position of GPS receiver (time to first fix) could be long [3]. For example, in urban cities where tall buildings are common, the calculation time for the position of the receiver may be more than one minute [11]. Longer processing means higher power consumption for GPS receiver. This becomes an issue for GPS receivers embedded in battery-powered devices like smartphones. Due to the LOS requirement, GPS signals are inaccessible in enclosed environments and therefore, are not suitable for indoor navigation.

- A smartphone, in the context of this paper, is defined as mobile phone that runs on operating systems such as Android[2], iOS[3], BlackBerry[4] and Windows Mobile[5]. In recent years, Android mobile operating system (Gingerbread and later versions) has included built-in NFC capability. NFC is a short range and robust high frequency wireless communication technology which enables the exchange of data between devices. Google Nexus S[6] is the first Android smartphone model that incorporates NFC technology. It operates at the frequency of 13.56 MHz in the unregulated radio-frequency (RF) band and offers data transmission speeds of up to 424 kbits/s. The technology integrates both the smartcard and the reader into the smartphones, which enables them to write data onto passive tags and have their data read by any NFC readers. When two NFC devices are placed within close proximity, typically less than 10cm, contactless peer-to-peer data exchange can take place. NFC-enabled smartphones allow consumers to perform transactions, exchange contacts and connect to other similarly-enabled devices [12]. Thus, this technology has been used innovatively in various applications like payments, electronic key, attendance control system, ticketing, exchanging business cards and smart posters [12-14].

## System Design of I$^2$Navi

**Hardware:** I$^2$Navi exploits the ability of NFC-enabled smartphone to read data from NFC tags and transfer them to the customized I$^2$Navi navigation application for further processing in order to guide users in indoor navigation. A poster, which has an NFC tag embedded in it, is referred as smart poster in this paper. It consists of a unique identifier that stores information of its location. Smart posters function as kiosks in the I$^2$Navi system for users to determine their current position for use in the I$^2$Navi navigation application. The application displays path with directions to the intended destination on the floor plan, on the smartphone's screen. The number of smart posters required depends on the size and intricacy of the building. For instance, buildings with many floors and wings may need more smart posters for more effective navigation.

**Software:** The key components of the I$^2$Navi navigation application are illustrated in Figure 1. They consist 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 a smart poster whenever an Android NFC-enabled smartphone running the I$^2$Navi navigation application is placed near it. The coordinate information received is then sent to the User Interface Module where the corresponding floor plan, based on the current coordinates, is retrieved from the Information Module. Subsequently, the Navigation Module computes a suitable route based on the current location and provides the directions to a particular destination using information obtained from the Database Module. The suggested navigation route, along with the user's current location, will be marked on the floor plan and displayed on smartphone's screen through the User Interface Module. The Information Module provides additional information on the destination through web links which is managed by administrative staffs through a dedicated content management system (CMS) to ensure the information is always updated.

**System Implementation of I$^2$Navi:** A prototype of the I$^2$Navi system has been implemented at FOE, MMU, covering numerous locations including laboratories, admin offices, staff rooms and classrooms. Using the system, students and visitors are able to find and / or explore the faculty building easily through the I$^2$Navi navigation application running on their Android NFC-enabled smartphones. The NFC tags (NXP Semiconductors NTAG203 (F)) which store the

[2]See http://www.android.com

[3]See http://www.apple.com/ios

[4]See http://www.blackberry.com.my/software/smartphones/blackberry-10-os.html

[5]See http://www.microsoft.com/windowsphone/en-us/default

[6]See http://www.nfcworld.com/nfc-phones-list

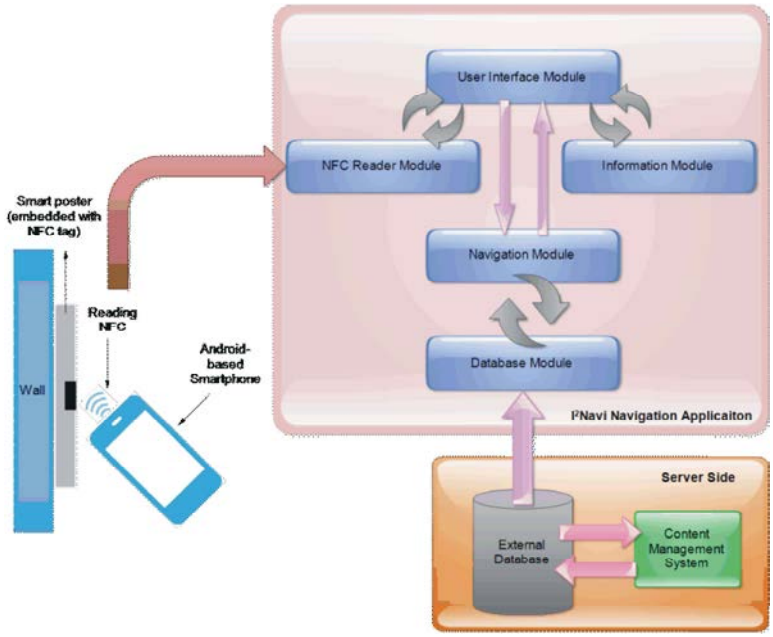
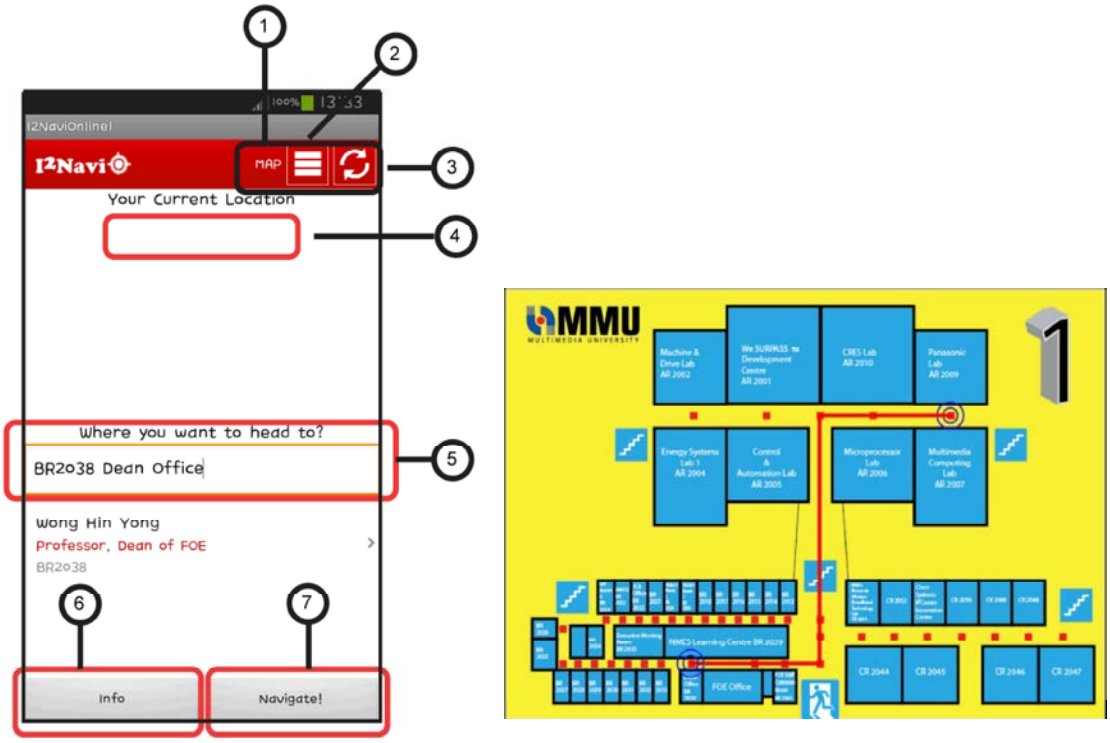



Fig. 1: Software components of the I²Navi navigation application




(a) Main interface: (1) Browse floor maps. (2) View staff details. (3) Update information online. (4) Information on current location. (5) Input destination. (6) View more information of destination. (7) Start navigation process.

(b) I²Navi displaying guided path for the FOE's floor plan

Fig. 2: User Interface of the I²Navi Application

Table 1: Evaluation result of the I²Navi system

| Item | | Mean (1-6) |
|---|---|---|
| BA1. | The functions in I²Navi are simple and robust. | 5.00 |
| BB2. | I²Navi detects my current location accurately. | 5.44 |
| BB3. | I²Navi is able to navigate me to desired location. | 5.50 |
| BB4. | Tapping on the poster is sensitive enough to obtain my current location. | 5.13 |
| C1. | Interaction with the I²Navi is intuitive and clear. | 5.19 |
| D1. | I intend to use the I²Navi in the future. | 5.13 |

coordinates of their locations are embedded in various advertisement / information smart posters. These are then placed at specific locations within the building. Users can tap their NFC-enabled smartphones on the designated "tap here" spot on the smart posters, while running the I²Navi application, to obtain their current location. Subsequently, they can input their intended destination, as illustrated in Figure 2(a). Once a destination is set, additional information relating to that location, such as the staff-in-charge, can be obtained by tapping on the "Info" button.

Tapping on the "Navigate!" button starts the navigation process. A floor plan is displayed with both the current and destination locations marked, as shown in Figure 2(b). As users advance along the marked route, they may tap their smartphones on other smart posters (if any) to confirm that they are on the right track.

## RESULTS AND DISCUSSION

An evaluation of the I²Navi system was conducted at FOE, MMU by a group of 16 randomly chosen undergraduate students. The evaluation process began with the participants given a demonstration of the I²Navi system by a facilitator. Subsequently, participants were given the task of locating a particular room within the FOE using the system, with minimum help from the facilitator. At the completion of the process, participants were requested to fill up a 6-point Likert-scale questionnaire, with choices ranging from 1 (strong disagreement/very low) to 6 (strong agreement/ very high).

The result of the I²Navi system evaluation is summarized in Table 1. In a gist, the participants were satisfied with the performance of the system. They find the functions provided by I²Navi simple and robust (BA1, m=5) and it accurately determined their current locations (BB2, m=5.44). All the participants either agreed or strongly agreed that the I²Navi system is able to guide them in locating their desired location (BB3, m=5.50). The results also indicated that the NFC tag embedded in smart poster is sensitive enough for this application (BB4, m=5.13). This is shown in Fig. 3.

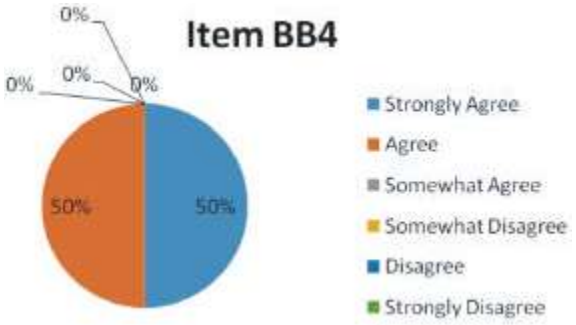



Fig. 3: Responses of Participants towards Ability of I²Navi to Navigate

The fact that during the evaluation process, most of the participants did not refer to additional smart posters after the first poster for further information when looking for their destination is noteworthy. However, this may be due to the relatively simple layout of the FOE building itself and cannot conclusively rule out the usefulness of having multiple smart posters along the way in larger or more intricate building. As for the user interface, the participants agree that it is intuitive and clear (C1, m=5.19), which enabled most of the users to operate the application without a lot of assistance. On the whole, majority of the participants felt positively about the I²Navi system and would use it in future when it is fully implemented within the university (D1, m=5.13).

## CONCLUSION

This paper presented a feasible and reliable indoor navigation system utilizing NFC and smartphone technologies through the prototype of I²Navi implemented at FOE, MMU, to help students and visitors to locate offices, rooms, labs etc., quickly and easily. The cost of this system is kept low with the use of relatively cheap passive NFC tags embedded in smart posters. The evaluation of the prototype by a group of randomly chosen undergraduate students returned encouraging responses specifically the system is able to guide them locating place of interest within a building accurately and

easily. However, more extensive evaluations should be carried out in the future with a larger coverage area and a larger group of participants to obtain more accurate feedback on the system.

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