Development of an Integrated Navigation System for Visually Impaired Pilgrims (VIPNAV)

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***Abstract*— Indicating the position for people who are visiting places for the first time is really challenge for drifters' people and more complex task to know the current position for blind people. Reaching a specific destination in unfamiliar environments is a real challenge for people with a vision disability, even if they use a white cane or guide dog, or the sighted people who able to see but they are drifters. The focus of this paper is a survey of exploratory study of the available technologies to come up with applicable suggested technologies which could be used to develop an outdoor/indoor Integrated Navigational System for Sighted or Visually Impaired Pilgrims (VIPNAV). VIPNAV will be composed of two integrated navigation systems: Global Navigation Satellite System (GNSS) and Radio Frequency Identification (RFID) System. The main target of this research is to proof of concept of that VIPNAV is an applicable system that may help blind and visually impaired (BVI) people and drifters sighted people to know their current position precisely which may contribute and used in further research as navigation system to assist any kind of pilgrims to do specific hajj tasks independently even they were blind people. The services that VIPNAV produce for BVI or drifters people include assistance to identify their current position precisely, and it could be used at another research to produce a navigation system that assist pilgrims to guide them to their desired destinations such as Jamarat and their temporary accommodation in Mina (their tents).**

***Index Terms*— Navigation, Visually Impaired Pilgrims, RFID and GNSS**

I. INTRODUCTION

REACHING a specific destination in unfamiliar environments is a real challenge for people with a vision disability, even if they use a white cane or guide dog. The focus of this research is to produce a positioning solution of an outdoor/indoor integrated Navigational system for Visually Impaired Pilgrims (VIPNAV). The main target of VIPNAV is to produce a system that helps sighted, blind and visually impaired (BVI) people to determine their current position accurately. That proposed positioning technique could be used in further research in navigation system which may assist pilgrims to do specific hajj tasks independently even they were blind people. The services that VIPNAV produce for BVI or sighted drifters people include assistance to identify their current position precisely.

In the navigational literature, several applications have been developed to assist BVI people. Most are designed to work in outdoor environments and work ineffectively in indoor environments. Furthermore, the major limitation of most navigation applications systems which designed to assist blind people are basing on famous addressing method such as street name, unit number and so on. In contrast, Mina and holy areas lacking to any addressing technique. Therefore, the proposed system would give the pilgrim opportunity to add all points of interest for him in the application such as Aljammarat, Alrahma Mountain and his tent No. Furthermore, there are no commercially available integrated navigation systems to assist BVI people to determine their current positions independently precisely particularly in environments they are visiting for the first time. This highlights the need to further address the research challenges.

Considering this problem, the main focus of this research is to investigate and suggest an integrated positioning system that should be suitable to assist sighted or BVI people in-between and outside tents in Mina and provide the pilgrims with their current location information once they need it

VIPNAV has three components: Global Navigation Satellite Systems (GNSS), active radio frequency identification (RFID) and Smart mobile phone. The integrated term refers to multiple services providing for BVI people. The first is positioning, which aims to assist BVI people to indicate their current location precisely. Positioning in VIPNAV systems should be done by GNSS/RFID for outdoor and RFID-only for indoor, with 2-m accuracy. The developed RFID positioning algorithm is based on using TURCK (U Grok It) UHF RFID Reader which attached to the smart phone to make the user cell phone able to read the RFID tags.

The second service which is not presented in this paper,

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produced for sighted or BVI people by VIPNAV is navigation, which aims to assist BVI people to reach their desired destination. Navigation includes positioning based on a developed positioning algorithm, determining the most preferable path for the user from their current location to the destination through the shortest path in most cases, and detection of deviation of the user from the suggested path to recalculate the path to the destination from the wrong location, as far as is possible. The required infrastructure should be prepared in Mina by distributing the RFID tags on Mina map to reach the benefit of VIPNAV Services.

II. OBJECTIVE AND APPROACH

The objectives of this paper are threefold. The first objective is to develop an indoor positioning system for drifters or visually impaired pilgrims (VIPNAV) using Radio Frequency Identification (RFID) system. The system should ensure the main service, assistance for drifters or visually impaired people to identify their current position precisely indoor and outdoor, prepare that positioning technique to be used in further research as a navigation system to be used to guide drifters or visually impaired people to reach their desired destinations such as Jamarat and their tent, detection of the deviation of the user from the suggested path and then, recalculating the path to the destination from the wrong location.

The second objective is to develop an outdoor positioning system for sighted or visually impaired pilgrims (VIPNAV) using Global Navigation Satellite System (GNSS). The US Global Positioning System (GPS) is the mainstay GNSS; therefore, it will be employed to the outdoor VIPNAV.

The integration of the two systems is the third objective. This system will be used for areas where GPS satellites drop to less than 4 satellites.

III. LITERATURE REVIEW

Many localisation systems have been developed, such as those by Najera et al. (2011), Ni et al. (2004), and Papapostolou and Chaouchi (2011). Some of these works can be extended into positioning to assist people with visual impairments using RFID technology (Tesoriero et al. 2008). These works can be classified into two groups, as follows:

A) Global Navigation Satellite System (GNSS)

The U.S. Global Positioning System (GPS) is a Global Navigation Satellite System (GNSS) that has been the mainstay of surveying and navigation techniques for almost three decades (Al-Shaery, 2013). GPS is a satellite navigation system developed and maintained by the U.S. Department of Defense (DoD) since the late 1970s. GPS was originally deployed to meet the military requirements for accurate position, velocity and time (PVT) in a world reference system on land, at sea, in air and space. However, since 1983 civilian use has been promoted following the Korean Airflight 007 tragedy (Hofmann-Wellenhof et al., 2008). In 2000, this was considerably accelerated by the President Clinton's order to switch off "selective availability" – an intentional degradation of the navigation message data for civilian use.

Currently, there are more than 30 operational satellites orbiting the Earth in six near-circular orbits with a semi-major axis of approximately 22,200 kilometres and 55˚ inclination angle of the orbit planes with respect to the equator. GPS has been in full operational capability (FOC) status since 1995. There are four types of measurements available from a typical GNSS receiver: pseudorange, carrier phase, doppler and raw signal strength measurements. However, the most commonly used GPS positioning measurements are pseudorange and carrier phase. The former is unambiguous (i.e., a direct distance measurement) but it is a noisier measurement. The latter is very precise (noise below the centimetre level) but it is an "ambiguous" measurement, as it is biased by an unknown number of complete carrier cycles (known as the integer ambiguity).

The performance of GPS in terms of accuracy, availability and reliability is dependent on the number of satellites being tracked by the user receiver. That is, the positioning accuracy of GPS can be degraded in so-called 'urban canyon' environments where the number of visible satellites is limited (Al-Shaery, 2011). Furthermore, GPS cannot work indoor because the signals are blocked by building walls. However, augmenting GPS with another technologies can enhance its performance in urban canyon or indoor. There are variety of technologies can be used for this purpose such as wifi, RFID, and Bluetooth.

B) Active RFID System

A system based on active RFID developed by Oktem et al. (2008) uses the more costly strategy of distributing transmitters (readers) in the ceiling for triangulation purposes then applies the RSSI technique to estimate the position of a tag carried by the user. In contrast Alghamdi and van Schyndel (2012), Alghamdi et al. (2013) and Alghamdi et al. (2014) produced positioning algorithm that based on distribution of RFID tags, their algorithm based on a combination of RRS and Attenuation control to reach accuracy around 2 m, then their system been tested on real blind participants as shown in Alghamdi et al. (2014).

Chumkamon et al. (2008) tried to use the ultra-high frequency RFID system within a proximity range up to 10-15 m using general packet radio service networks for a navigation device for blind people but they found that there were delay problems in their system. Mooi et al. (2010) produced an efficient RFID tag-placement framework for an indoor navigation system for blind people, but it did not solve any of the problems of dependency, short range or cost and it merely produced a guideline for tag placement in indoor environments.

C) Passive RFID Tag Systems

The work of Fukasawa and Magatani (2012), and Seto and Magatani (2009) was based on using colour sensors and a passive RFID system, which required a distance of less than 50 cm to communicate between the tag and the cane. Ganz et al. (2010; 2011) used a passive RFID system that required a distance of 23 cm, and the system of Liu et al. (2007) required less than 10 cm, to transfer data from the tag to the reader. Also, Di Giampaolo (2010) produced an indoor navigation system based on passive RFID technology that indicated the location of users based on a grid of passive tags located on the ceiling at known positions. da Silva Cascalheira et al. (2012) succeeded in indicating the middle of a door by computing the power of the receiving signal, then comparing signals to choose the largest one, which represents the middle of the door. To achieve this goal, it was necessary to deploy an antenna on the doors and a pair of antennas with the receiver. It also needed an RF-DC converter radio frequency to direct a current and microcontroller unit (MCU) to compare the signal strength of each antenna, which was useful in assisting blind people to enter or exit rooms through its doors but it did not guide them to those doors.

Faria et al. (2010) and Shiizu et al. (2007) each combined electronic white canes with RFID technology to improve guidance systems for people with visual impairments. The most advantageous feature of passive RFID is that it does not require an external power source because it depends on a magnetic field through absorbing the energy radiated by the reader to transfer data from the tag to the reader. However, this kind of communication requires a short detection range, which is a disadvantage because the system will perform best when the user is inside its range (which is very narrow in almost all passive systems); therefore it requires another technology or method to guide blind people to the points of that system. Kiers et al. (2011) and Szeto and Sharma (2007) both stated that they will develop a wider range with new passive tags, which may contribute to solving some of these limitations.

IV. RESEARCH METHODOLOGY

Positioning of a mobile device can be performed by the use of several observables which some of them are listed in Table I (Chen and Guinness, 2014). The process of determining the position of a body is based on the use of observables which are referenced in a specific coordinate system. It is assumed that the Map of Mina is included in the proposed application as a database file where each particular location been identified via a unique identification number which can be achieved by the use of a geo-referenced map. The proposed application uses GPS in open areas whereas RFID-alone is used indoor. Moreover, in areas where the number of GPS satellites is less than 4, RFID measurement will augment the navigation system. This paper focuses on the part of positioning at indoor environment using passive RFID system via mobile application. Through this research a positioning system been conducted and tested on real experiments in indoor environment and presented as a mobile positioning application to explore any potential limitations, also as proof of concept of the proposed positioning application could be used at indoor environments in the Holy area in the coming navigation research. The produced application is made on mobile platform; so sighted or BVI pilgrims can use their smart phone mobiles. Indoor positioning using Passive RFID module is implemented and presented here.

TABLE I: MOBILE POSITIONING OBSERVABLES

Observable	Sensor or Network
Range	GNSS receiver, Cellular networks
Ranging Difference	GNSS receiver, Cellular networks
Travelled Distance	Accelerometer, Camera
Speed	GNSS receiver, Accelerometer, Camera
Acceleration	Accelerometer
Angle/Azimuth	Digital Compass, cellular network
Angle rates	Gyroscope
Signal Strength	WLAN, Bluetooth, RFID, cellular network
Cell-ID	MAC address, base station in cellular network
Image/image features	Camera

A) Indoor Module

In this module, the positioning application uses RFID signal when GPS satellites are completely blocked or provide inaccurate location information. Therefore, RFID tags will perform the task of the satellites. A user will use his smart phone mobile as a receiver with RFID reader attached to the mobile as shown in figure1 with TURCK the device that appears in figure 2. TURCK has been used in the system to make the smart phone able to deal with RFID signal. Because of the smart phone unable to read RFID signal by itself like Bluetooth or NFC which embedded in the smart phone, so TURCK used and attached to the phone in the proposed positioning system to make the system able to determine the position of the user basing on the locations of distributed RFID passive tags, which been chosen for the following advantage:

- Its availability of RFID readers (mobile cell phone) with omnidirectional capability to transmit signal for 360° and RFID tag receives and responds to the initial signal from the reader from any angle.
- Its reading distance round 2.5 m, so it is not require very short reading distance to detect the tag as an original passive RFID technology.
- RFID reader has been designed to be attached device with the smart cell phone via audio port.

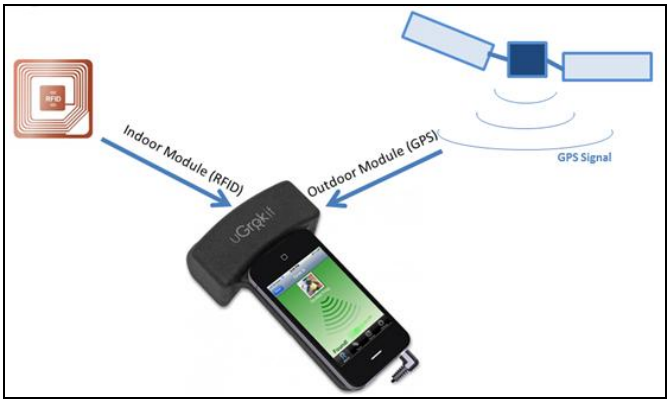

Fig. 1. Positioning Modules

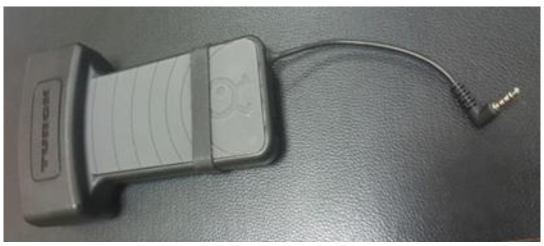

Fig. 2. TURCK (U Grok It) UHF

The availability of RFID passive tags which are very cheap (less than $1 each) and do not require battery to be detected by the RFID reader. Therefore, it is reasonable to argue that the required infrastructure based on distribution of these RFID tags everywhere.

V. EXPERIMENTS AND RESULTS

To evaluate the proposed positioning system experiments been conducted. The experiments have been done in indoor environment inside building of Computers and Information Technology College in Taif University, particularly in the Computer Science department which its map appears in Fig. 3. The required infrastructure been constructed through distribution of passive RFID tags on the offices in the department as shown in Fig. 4. Then the experiments been conducted in 10 locations in the middle of the corridor.

In all 10 positions the detected tags which appear in Table II were corrects and supposed to be detected. But in case of more than one tag were detected, that may cause concern for the users who are blind, that limitation been happened because of the reading distance was on the maximum range which called "Locate Distance" shown in Fig. 5. The tag could be detected in 3 m distance. As a suggested solution to that ambiguity which may be facing by blind user because of each tag represents a different location, the reading distance between the user and the tag should be decreased to second level which called "Inventory Short Range" around 1.5 m to detect at most one tag as it possible. To guarantee the success of the proposed positioning system we plan to conduct that test by blind person who are first time visiting experiments location and marks any potentials other limitations.

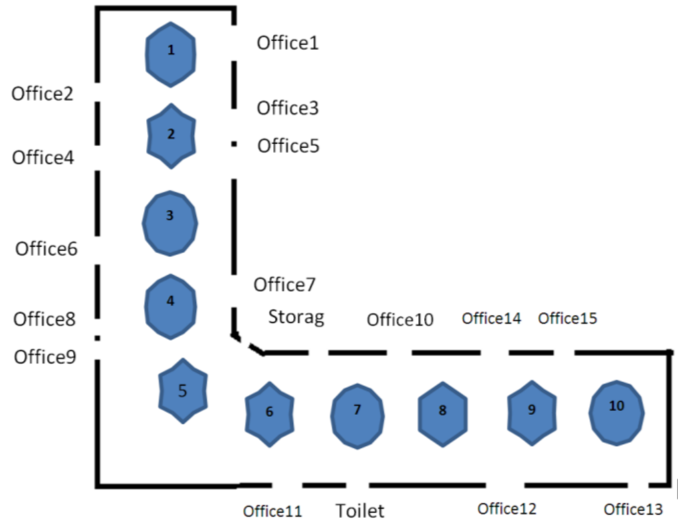

Fig. 3. Computer Science Department map

TABLE II. EXPERIMENTS TEST AND RESULTS

The user location, represented by the location of the Mobile as RFID reader	Exact location:	The detected RFID tag.	Supposed to be detected.
1	Middle & more bias to right side	Office 2	✓
	Middle & more bias to left side	Office 1	✓
2	Middle & more bias to right side	Office 4	✓
	Middle & more bias to left side	Office 3 & office 5	✓
3	Middle & more bias to right side	Office 6	✓
	Middle & more bias to left side	None	✓
4	Middle & more bias to right side	Office 8 & office 9	✓
	Middle & more bias to left side	Office 7	✓
5	Middle & more bias to right side	None	✓
	Middle & more bias to left side	Storage	✓
6	Middle & more bias to right side	Office 11	✓
	Middle & more bias to left side	storage	✓
7	Middle & more bias to right side	Toilet	✓
	Middle & more bias to left side	Office 10	✓
8	Middle & more bias to right side	Office 12	✓
	Middle & more bias to left side	Office 10 & office 14	✓
9	Middle & more bias to right side	Office 12	✓
	Middle & more bias to left side	Office 14 & office 15	✓
10	Middle & more bias to right side	Office 13	✓
	Middle & more bias to left side	Office 15	✓

VI. CONCLUSION

This research aimed to propose a positioning service for pilgrims who are drifters or visually impaired people to assist them to indicate their location accurately. The focus of the paper is a proof of concept of using passive RFID technology for positioning purpose at indoor environment to be produced as service for pilgrims in the holy area, particularly in "Mina". Experiments have been conducted in indoor environment by the researcher and achieved encouraging results to indicate the position accurately. As future work the researcher will apply that positioning system by blind people then using that positioning technique would be used for navigation purpose to enhance the mobility ability for drifts or blind pilgrims to move to their desired destinations independently.

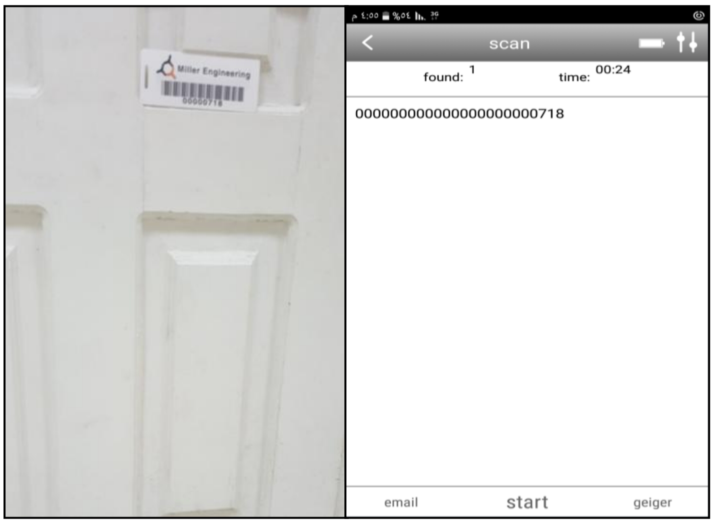

Fig. 4. Passive RFID tag to identify offices in experiments

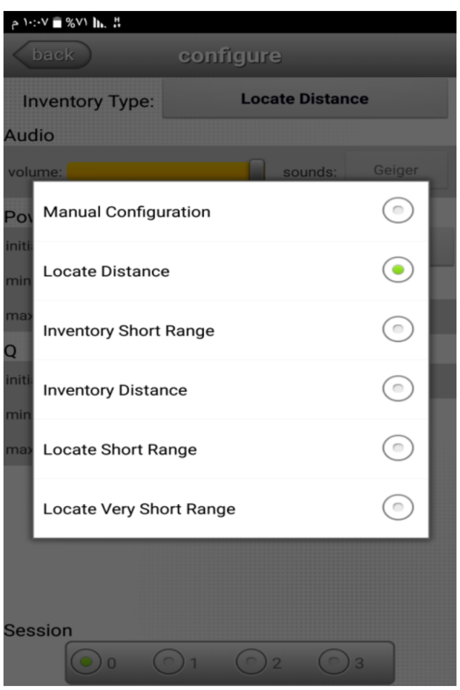

Fig. 5. Configiration of the sensetivity of TURCK

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