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Passive RFID Indoor Localisation to Aid the Blind

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***Abstract*— The ability to navigate effectively in an indoor environment is one that is important to everyone. Blind and Partially Sighted (BPS) people have the limitation of not being able to use visual cues such as signs and landmarks to aid their navigation. Tests were conducted into the use of RFID technology for assisting the BPS with indoor positioning and object recognition.**

The Nottingham Geospatial Building at the University of Nottingham serves as a test-bed for many dynamic positioning research projects. Along with its unique roof based test-track facility, the Geodesy Lab and the large open-plan office area are fitted with passive HF (13.56 MHz) tags under the carpet. The tags are located at 30cm intervals in the Geodesy Lab while in the open-plan area, around the outer perimeter the tags are generally located at 30cm intervals and on the inside at 60cm intervals. The tags are 50mm x 80mm in size and have 2K bits of memory.

A survey was conducted where the location, ID and Received Signal Strength Indicator of the tags were recorded. A novel database, and routing algorithm was developed which guided the user (wearing a lightweight Wi-Fi enabled RFID reader with foot-mounted antenna) using voice commands. The voice commands were activated by linking the navigation program with the eSpeak text-to-speech voice synthesis library. In addition, the system was tested for use in identifying objects such as Fire Exits and office furniture. The system was able to guide the user effectively from one location to the next with high accuracy (15 - 30cm). However it had the limitation of requiring a short range, in the order of 20cm, between the reader's antenna and the tag. The strengths and limitations of such a system and its application to navigating the blind were explored.

Keywords: RFID; indoor positioning; BPS

I. INTRODUCTION

Radio Frequency Identification (RFID) is based on wireless communication, utilizing radio waves. It is similar to other wireless technologies such as Zigbee, WiFi and Bluetooth. These technologies have been developed for different uses and as a result have different functionalities but they share some similar characteristics.

RFID is used for a wide range of applications such as entry cards, pallet and goods tracking, clothes inventory and much more. In recent years RFID technology has become popular and inexpensive as it is now mass produced. In addition, its use has been extended into the area of indoor localisation. It requires a reader and a tag or transponder which is an integrated circuit with an antenna and a memory chip. There are two types of RFID tags – active and passive tags. Active tags require a power source such as a battery and broadcast their data at preset time intervals. Passive tags do not require a power source but rather are powered by the RF energy from the reader when in range of the reader. Both active and passive tags operate in different frequency ranges, from low frequency to high frequency (HF) to UHF. These have varying strengths and weaknesses in terms of range and ability of the signal to permeate through materials.

RFID operates in the unlicensed Industrial, Scientific and Medical (ISM) spectrum space, though due to regulations in each country the exact frequencies which make up ISM may vary. These operating frequencies are usually considered to be arranged into four main frequency bands and Table 1 shows these bands and the more common frequencies used for RFID systems [1].

Significant research has been carried out in the robotics field in terms of localisation using RFID tags. As part of research into robotics for assisted living, researchers at Waseda University, Japan have conducted tests into indoor position estimation of a mobile robot on a lattice of RFID tags. Real-time localisation of the robots was achieved by combining data from multiple RFID readers with data from the wheel encoders on the robot [2], [3].

The University of Florida has carried out research into the use of passive RFID tags to assist the blind in navigating around their campus [4]. Other work has also been done in Italy by the SEcure and SAfe MObility NETwork (SesamoNet) group in using passive RFID tags to assist the

TABLE 1. RFID OPERATING FREQUENCIES AND ASSOCIATED CHARACTERISTICS [1]

Band	**LF Low Frequency**	**HF High Frequency**	**UHF Ultra High Frequency**	**Microwave**
Frequency	30 – 300kHz	3 – 30 MHz	300 MHz – 3GHz	2 – 30 GHz
Typical RFID Frequencies	125 – 134 kHz	13.56 MHz	433 MHz or 865 – 956 MHz 2.45 GHz	2.45 GHz
Approximate Read Range	Less than 0.5m	Up to 1.5m	433 MHz = up to 100metres 865-956 MHz = 0.5 to 5 metres	Up to 10m
Typical Data Transfer Rate	less than 1 kilobit per second (kbit/s)	Approximately 25 kbit/s	433–956 = 30 kbit/s 2.45 =100 kbit/s	Up to 100 kbit/s
Characteristics	Short-range, low data transfer rate, penetrates water but not metal.	Higher ranges, reasonable data rate (similar to GSM phone), penetrates water but not metal.	Long ranges, high data rate, concurrent read of <100 items, cannot penetrate water or metals.	Long range, high data rate, cannot penetrate water or metal.
Typical Use	Animal ID, Car immobilizer.	Smart Labels, Contact-less travel cards, Access and Security.	Specialist animal tracking, Logistics, Industrial/Scientific/ Medical applications.	Moving vehicle toll, Retail Supply Chain Management.

visually impaired in navigation. The University of Rome “Sapienza” has been involved in this work [5].

In the age of ubiquitous computing, technology such as RFID can be incorporated into the building structure to enhance the usability and comfort of disabled occupants and visitors.

II. Passive RFID – Indoor Positioning and Object Identification

A. *Passive RFID Tags*

Passive RFID HF (13.56 MHz) tags were fitted on the floorboards under the carpet of the B floor open office area (B05) and the Geodesy Lab of the Nottingham Geospatial Building (NGB). The tags were placed at 30cm intervals in the Geodesy Lab while in the open area of the B floor, around the outer perimeter the tags were generally placed at 30cm intervals and on the inside at 60cm intervals. The tags are 50mm x 80mm in size and have 2K bits of memory. Fig. 1 shows a sample of the “Tag-it” HF RFID tags used.

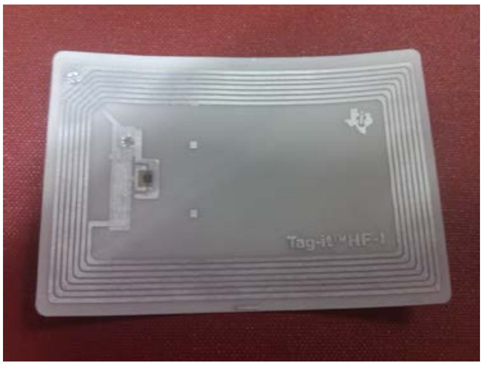

Figure 1. ISO 15693 HF (13.56MHz) RFID Tag

There are two ways in which RFID tags can be used for positioning:

i) The tag location and other information such as object id, vicinity information or other details are written directly to the memory of the tag.

ii) The tag location and other information are stored in a database along with the Unique ID (UID) of each tag.

Option (ii) was chosen to be tested on the B floor of the NGB. This option has the advantage of being quicker to set up, as well as more flexible as the database can be easily updated if required. While for option (i) even though the data memory is re-writable, updating information would require visiting each tag manually with the RFID reader which would take a longer time than option (ii).

Although it has been mentioned that option (ii) is quicker than option (i) it nevertheless requires some amount of time to survey the area in order to build up the database. This was done by attaching the RFID reader’s antenna to the heel of the user’s shoe and walking up and down, with a tape measure used to define the position of each tag (Fig. 2).

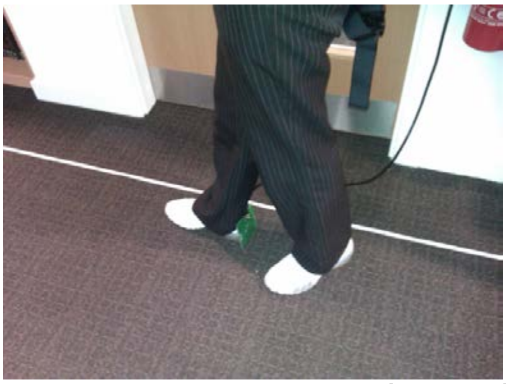

Figure 2. Mapping RFID Tags Using Foot-Mounted Antenna and Tape

B. Mapping the RFID Tags

The tag UID and Received Signal Strength Indicator (RSSI) were recorded during the survey stage. Fig. 3 shows an overview of the office area and the tags in the outer perimeter. The tags that were located under office furniture such as cabinets could not be surveyed At this initial stage, only the tags on the outer perimeter were surveyed.

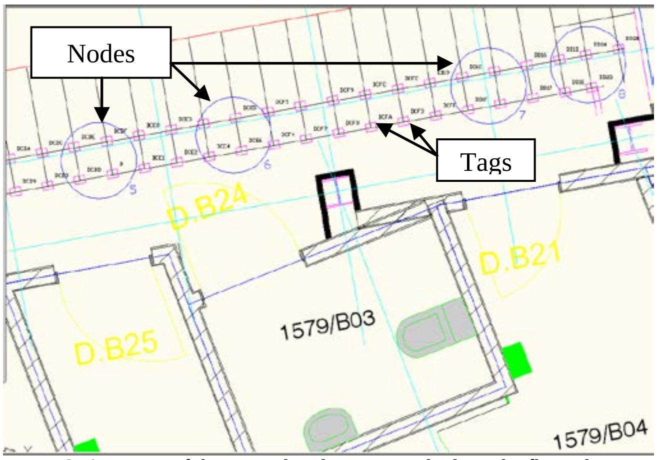

Figure 3. A section of the tag and node map overlaid on the floor plan

III. NODES AND TAG DATABASE

Key points such as in front of office doors, exit doors or toilets where selected as nodes (Fig. 3) and the RFID tags belonging to each node identified. A node table was then populated, listing all the nodes and their relative location relationship with each other. Table 2 shows an extract of the Node Table. It gives the node number of the node to the north, south, east and west of each individual node. This is in a local reference plane relative to the open plan office area (though roughly aligned to North).

TABLE 2. EXTRACT OF NODE TABLE

Node#	Node_N	Node_S	Node_E	Node_W
1	191	2	0	0
2	1	3	0	0
3	2	0	4	0
4	16	0	5	3
5	0	0	6	4
6	0	0	7	5
7	0	0	8	6
8	9	0	0	7

A tag database table was built as shown in Table 3. The Tag ID is based on the last four letters of the Tag UID that was collected during the survey/mapping stage. The number of the Node that the tag belongs to is recorded in the 'in_Node' field. If the tag does not belong to a node then a '0' is recorded.

An XML template for the database table was designed as shown in Fig. 4.

```
<tags>
        <tag id = "DD1F">
                <location>
                        <lat>1234.5</lat>
                        <long>5678.9</long>
                        <delta>
                                <x>41.7</x>
                                <y>-9.1</y>
                        </delta>
                </location>
                <object type = "LADIES"> </object>
                <in_Node> 7 </in_Node>
                <connection>
                        <Node_N>0</Node_N>
                        <Node_S>0</Node_S>
                        <Node_E>8</Node_E>
                        <Node_W>6</Node_W>
                </connection>
        </tag id>
        <tag id = "DD1C">
                …
</tags>
```

Figure 4. XML template for tag database

The database table can thus be exported in XML format in order to make it available to other users and interoperable with other systems.

The two RFID readers at the Nottingham Geospatial Institute are the Obid MR200-W and the M02.M8 by Feig Electronics. The MR200-W is Wi-Fi enabled, thus data can be sent from the reader to a computer or data-logger wirelessly. The M02.M8 is small in size at 87mm by 50mm. It has an in-built multiplexer, thus it is able to connect to up to 8 antennas.

The MR200 was used for these tests due to this wireless capability and its ability to output several data types such as RSSI and stored tag data.

A. Route Planner

A program was written to read the information received by the RFID reader and, based on the current location that the RFID reader identifies, it plans the route to the destination selected by the user. The route will be defined by the nodes along the way to the desired destination. E.g. Node 3 → Node 4 → Node 5.

B. Real-time Navigation Guidance

Another program was written to interface with the route planning routine. As the user walks, the RFID reader gets the tag id and other information such as RSSI. It compares the tag id with the data in the Node Table, Tag Database and Route defined by the route planner. Based on this the program gives the user voice directions to the next node. When the user arrives at that node they get instructions to the next node along the route until they are informed by the program that they have arrived at their destination.

C. Voice Comands

The voice commands are activated by linking the Navigation Guidance program with the voice synthesis library

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TABLE 3. EXTRACT OF TAG DATABASE

Tag_ID	x	y	Obj_name	in_Node	Node_N	Node_S	Node_E	Node_W
DCDE	23.1	-8.8	MENS	5	0	0	6	4
DCDF	23.4	-8.8	MENS	5	0	0	6	4
DCE1	23.7	-9.1	N	0	0	0	0	0
DCE0	23.7	-8.8	N	0	0	0	0	0
DCE2	30.0	-9.1	N	0	0	0	0	0
DCE3	30.0	-8.8	N	0	0	0	0	0
DCE4	30.3	-9.1	DISAB	6	0	0	7	5
DCE6	30.6	-9.1	DISAB	6	0	0	7	5
DCE5	30.6	-8.8	DISAB	6	0	0	7	5
DCF4	30.9	-9.1	N	0	0	0	0	0
DCF8	40.5	-9.1	N	0	0	0	0	0
DCFD	41.1	-9.1	N	0	0	0	0	0
DD1F	41.7	-9.1	LADIES	7	0	0	8	6

called eSpeak, which is available for converting text to speech. eSpeak is a compact open source software speech synthesizer for English and other languages. It is available for Windows and Linux as well as a version for the Android platform [http://espeak.sourceforge.net/]. Using a text to speech converter has the advantage of being flexible and easily adjustable as new commands/directions can be added without difficulty. However it has the disadvantage of not sounding natural. Pre-recorded voice commands can also be used.

IV. Algorithm for Real-Time Route Planning and Navigation Guidance Based on the Passive RFID Tags

Fig. 5 shows a flowchart for the route planning and navigation program which can be used for indoor positioning.

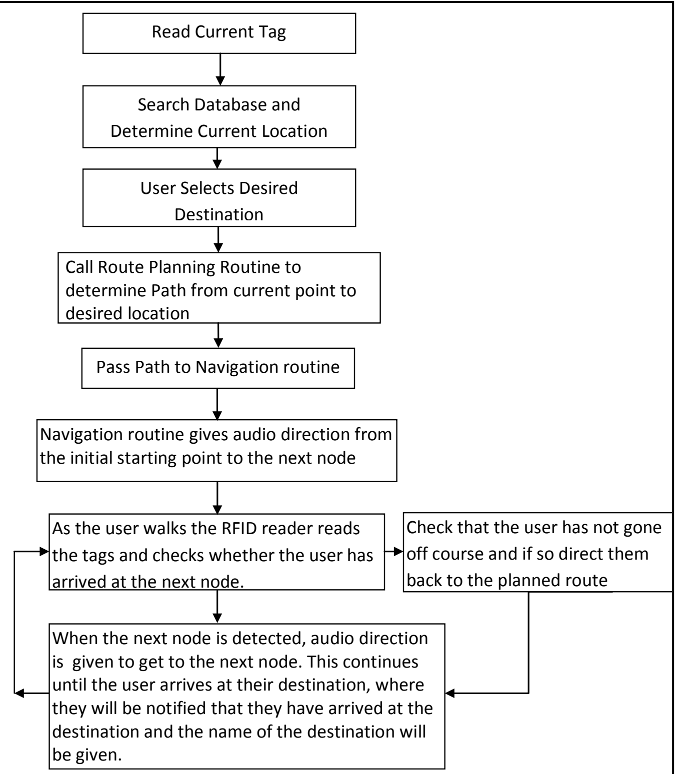

Figure 5. Flowchart for RFID based navigation program

V. RFID for Object Identification

The RFID tags can also be further used for object recognition in the form of identifying the location of office furniture for example. This can then be included in the 'Object_ID' field of the node table and the following XML lines can be added to the XML template:

<object type = "CHAIR">

<position type = "delta"> 10 10</position>

Fig. 6 shows an RFID tag located at the corner of an office desk.

Figure 6. RFID Tag on Office Desk Corner

VI. PRIVACY, LEGISLATION AND REGULATIONS

The European Commission launched a public consultation on RFID in 2006. This followed on from the RFID inter-service group established to coordinate the collecting, analysis and internal dissemination of information concerning the use of RFID technology. Outputs from the public consultation are available as an online consultation document.

Consumer and civil liberties groups are raising issues concerning what privacy means in a technologically rich world. Technology specialists, supporters of RFID and privacy experts are beginning to engage with these groups in developing models of privacy threat and how to determine whether a proposed technology can be adjusted in order to meet concerns [1].

VII. CONCLUSION

The ability to navigate in an outdoor or indoor environment and recognise objects is one which is taken for granted by sighted people. However for the visually impaired this task is less 'trivial'. Way-finding or navigation is the means by which a person utilises their spatial orientation in order to move through the dynamic surroundings and arrive successfully at their destination [6]. This successful navigation requires continuous feedback from the environment. For the blind and partially sighted the visual cues, which are a significant aid to navigation, are either severely limited or non-existent. In the indoor context satellite based sensors such as GPS are ineffective therefore other sensors such as RFID have to be introduced in aiding indoor navigation for the BPS.

The lattice of passive RFID tags in the Nottingham Geospatial Building was mapped and this information was used to build a connectivity database. This database allowed indoor topology [7] to be defined, which then enabled the user to be guided within the indoor environment. Audio directions were provided by linking to a text to speech program (eSpeak). The ability to define indoor topology is an important aspect to navigation within an indoor environment, which is unlike the outdoor scenario where there is a defined road network structure. In the test conducted a wireless RFID reader was used. In this application the reader is mobile while the tags are static. This is the reverse of conventional applications such as goods tracking. Although the reader was wireless it required a PCB antenna which was mounted at the back of the user's shoe and this required a cable connection. The navigation program was run from a laptop which received information from the RFID reader and provided real-time audio guidance to the user. This was adequate for a proof of concept test, however for implementation the aim would be to run the program from a PDA or smart-phone and utilise smaller antennas which can be more discrete. The HF frequency chosen resulted in a short range of about 20 – 30 cm between the reader and tag which was a limitation. Using UHF tags would have offered a longer range, however in an indoor environment UHF suffers significantly from multipath and thus would have led to erroneous positioning results.

With miniaturisation of hardware and implementation on an everyday device such as a smart-phone this system has the potential to assist in indoor positioning and object recognition for the BPS. The passive tags can be incorporated into new building design or fitted into old ones.

The RFID system would also benefit from integration with other sensors such as the inertial sensors on a smart-phone. Further work is required to address the range issue as well as usability and human factors testing with blind users.

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