Evaluation and Improvements of an RFID Based Indoor Navigation System for Visually Impaired and Blind People

Martijn Kiers*, Elmar Krajnc**, Markus Dornhofer* and Werner Bischof*
*FH JOANNEUM University of Applied Sciences Department of Energy, Transport and Environmental Management, Kapfenberg, Austria. Email: martijn.kiers@fh-joanneum.at, markus.dornhofer@fh-joanneum.at, werner.bischof@fh-joanneum.at
**FH JOANNEUM University of Applied Sciences Department of Internettechnologies, Kapfenberg, Austria. Email: elmar.krajnc@fh-joanneum.at

Abstract—**In this paper we introduce the improvements made to the indoor navigationsystem "ways4all", based on passive RFID-tags, presented at IPIN 2010 [1]. The developed navigation method "Gerwei" is extended with a "z" axis, in addition to the "x" and "y" axes. So routing can be made across different levels. Furthermore, we tested the reading range of different passive low frequency tags (134,2 kHz). The reading range also depends on the kind of RFID-reader used. In the internal tests and in the real test at "Suedtirolerplatz", one of the busiest metro station in Vienna, Austria, a long cane RFID-reader [2] and a foot mounted RFID-reader were used. The first result shows that the software and the Bluetooth connections work in a convincing manner; all of the test persons were able to use the application and found their destination on their own and without any problems. The foot-mounted reader had a higher hit rate than the long cane, so this RFID-reader is preferred. The biggest deficit is the reading range of the tags, but new tags with a higher reading range are being developed by us. With this application the first step in a cheap, overall navigation system is made.**

Keywords: Indoor navigation system; RFID; visually impaired and blind people; Gerwei-method; Ways4all

I. Introduction

In the last few decades finding the way has become much easier. Technologies like GPS, Wi-Fi and GSM have paved the way for navigation with mobile devices. The prerequisites for this kind of navigation are a mobile navigation device, an open connection with satellites and the know-how to use the navigation. The main problem with GPS based navigation is the inaccuracy of the navigation, the deviation of which is up to five meters [3]. Therefore, this kind of navigation cannot be used by everybody. For visually impaired and blind people an inaccuracy of more than one meter can be deadly. For this reason they can only use this navigation as an audio-visual supplement when travelling. The next problem is that visually impaired and blind people need a continuous travelling aid. In the indoor areas, GPS is not available, which makes the use of indoor travelling for this group almost impossible. Yet, the new navigation system "ways4all" can increase the accessibility to the public transport system for this group of people.The main goal of our project is to develop an overall navigation system (for indoor and outdoor use) to support blind and handicapped people in finding their way. This way, the visually impaired and blind people can live an independent life. The first phase to reach this overall navigation system is to develop an indoor navigation system (INS) to be used inside the public transport stations and for finding ticket machines, toilets, departing platforms, etc.

II. Related work and our Project

Different methods can be used for positioning in Indoor Navigation (IN) or Location Based services (LBS). The most common finger printing techniques are WLAN-Access-Points (or the so called Digital Graffiti) [4] [5], Indoor GPS [6] or Ultra Wide Band (UWB) [7]. The disadvantages of using WLAN for LBS are the inaccuracy of up to five meters and the negative influences caused by metallic surfaces and magnetic fields [8] [9]. The electric fields produced by trains can also cause false position calculations based on WLAN positioning. When using Indoor GPS the accuracy varies from three meters to more than twenty meters, depending on the structure of the building and the materials used. [6]. The footprint (body geometry) calculated by UWB fluctuates even though the person does not move [7] which makes an accurate navigation difficult. None of these positioning methods is accurate enough for the navigation of visually impaired and blind people.

Other techniques which have recently been researched for LBS use ultrasonic sounds [10], Simultaneous Localization And Mapping (SLAM-method) [11] and inertial navigation [12]. These techniques are still in their early development stages and can not deliver the accuracy needed for IN for visually and blind people.

Another technology which can be used for LBS is RFID-tags. RFID technology for routing visually impaired and blind people in indoor areas is not a new technology, as has been shown in some examples: Sesamonet [2]; RFID in Robot-Assisted Indoor Navigation [13]; RFID Information Grid [14] and Indoor Navigation System for Visually Impaired [15].

However, these methods were developed to solve isolated problems and are not designed to lead the user from their original location all the way to their final destination. This is the difference between our project "ways4all" and other indoor navigation projects.

The key requerements of the system were as follows: no or hardly any new or special equipment for blind people; imbedding existing equipment and methods; routing without absolute coordinates; on-going route navigation from outdoor to indoor; easy to install; easy to use; low cost solution for the user, operator and public transport companies; simple way to record the tags; secure against vandalismus.

III. Indoor navigation system and the Gerwei method

A. Navigation system Description

The INS ”ways4all” uses passive RFID-tags to indentify routes, barriers and different means of public transport. The basis for the routing is the tactile guidance system (TGS). At all strategic spots inside the building (entrance, platforms, intersections) a passive RFID-tag is placed into the TGS and their unique code is stored in a MySQL database by the self developed recording-software. When travelling trough the building the RFID-reader reads the unique code of the RFID-tags and sends it to the user's smartphone by Bluetooth [1]. Before leaving, the user selecs a destination from a list of possible destinations in the building with their own smartphone using a screen reader (Talks, Talk back, Voices over). The smartphone checks the unique code and uses a Dijkstra algorithm and the blind person's profile to route the user. All the information necessary for routing the blind person is generated by the Gerwei-method developed by us [16]. The information given to the user are either navigation instructions (Left, in ten meters right, go downstairs) or location descriptions (e.g. You are at the (subway), No (1), at the (Suedtirolerplatz), on the way to destination (Reumanplatz)), depending on the settings in the user profile.

B. Long cane RFID reader vs. foot-mounted RFID reader

In the project Sesamonet a long cane with an RFID-reader is used to detect the tags (134.2 KHz RFID, LF Bluetooth Reader [2]). The use of a long cane causes minor problems during navigation. The long cane is mechanically stressed by the movement of the stick which can damage the built-in RFID Reader. Furthermore, the life span of a normal long cane is less than a year and the additional weight (approx. 300 grams) is problematic for long time use. So, we decided to do some tests with a standard RFI-reader (134.2 KHz RFID, LF Bluetooth Reader; type 222012) mounted on a shoe with a glued clip. The movement of the foot-mounted RFID-reader (FM-RFID-reader) is more centered on the tactile lines and the mechanical stress is much lower.

C. The extended Gerwei method

After the implementation of the Gerwei method in summer 2010, it was clear that the method had to be extended. To make it useable in bigger buildings, a ”z” axis was required in addition to the ”x” and ”y” axes. Every tag is situated

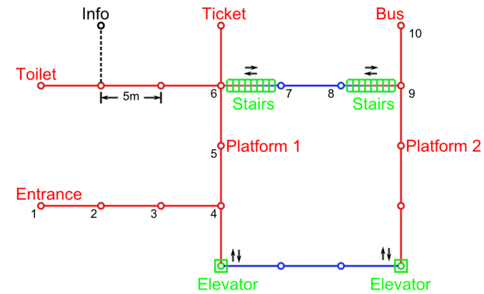

Fig. 1. Example Network for Indoor Routing

at a certain level and with the ”z” axis two more relations are possible for up and down (elevator) relations. If the level changes between two tags (+1 or -1) within one of the eight standard directions, this route section is a (moving) staircase. In our software, different user profiles are preprogrammed. For example: blind person, wheelchair user, physically handicapped or deaf person, etc. Each user can adjust his/her profile to their preferences. When calculating the optimum route, the user profile and the personal preferences are taken into account: a person in a wheelchair will not be routed over stairs as the system blocks all paths inside the database with the label 'stairs'. The elevator has to be used instead when changing the level, even if the way is longer. In the database and navigation software we use three types of tags: The Virtual Tags (VT), the Intermediate Tags (IT) and the Endpoint Tags (ET). VTs and ETs are possible destination points. VTs are not physical tags which have been built inside the building environment, but are markers for points of interest (POIs) inside the database and are used for destinations where no tactile guidance lines are available. ITs are actual position points inside the building environment, are used for routing only and cannot be selected as a destination.

D. Example routing network

In figure 1 we have a small example network. To simplify the example the distance between every tag is five meters. There are six ETs, which can be reached by the TGS and one VT (Info-counter) where no tactile system is available. A routing to all seven destinations is possible. Once the destination is selected and the first tag is read, the route is calculated. To positively identify the moving direction a second tag has to be read. If the next tag is on the routing list, then the user has chosen the right direction. Every time a tag is not on the routing list, a recalculation of the route is made. If one or more tags have been missed but the user is still on the TGS, then the routing instructions are still valid.

In figure 1 one VT (Info) is built inside the routing database. This VT can be chosen as an ET. The user is told to leave the tactile system and walk five meters before reaching the info-point. An additional routing with an inertial navigation system is planned in the next phase of the project, so that points away from the TGS can be reached.

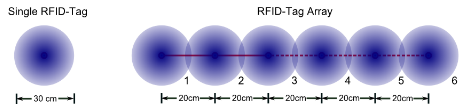

Fig. 2. Principle of the Tag Array (TA)

TABLE I
HIT RATE OF SINGLE TAGS AND TAG-ARRAYS

Arrangement	Single Tag	3 TA	4 TA	6 TA
User 1	14%	32%	36%	not tested
User 2	10%	30%	44%	not tested
User 3	10%	30%	40%	not tested
User 4	8%	48%	32%	not tested
Average	10,5%	35%	38%	not tested

IV. SYSTEM TESTS

A. Internal Tests

The first test case was a simulation of a TGS with built-in RFID-tags (card transponders Texas Instruments, 134.2 kHz, type RI-TRP-R4FF). For this we used a carpet with the width of a TGS in public buildings. The card transponders were mounted under the surface of the carpet. It was not possible to see or feel the tags. In the first pilot test only one tag was used to mark a strategic point on the navigation network. The test setup included eighteen RFID-tags, five of which were ETs on the test path and thirteen were ITs. The pilot test user (male, 29 years old) had no visual restrictions and was moving really slowly during the test; because of this the test person was able to find most of the tags. The hit rate of the tags was approx. 80%. This test was performed with both the long cane RFID-reader of Sesamonet as well as the FM-RFID-reader. The next test person was a blind male, 45 years old, with very good skills in navigating on the tactile system. The first impression was that the long cane with the RFID-reader was not usable. The long cane was too short, too heavy for long usage and the movement radius for a useful hit rate was too wide. The FM-RFID-reader does not have all these short-comings and worked very well during the test. The FM-RFID-reader was at the right position to read the built-in tags. It was not too heavy and the blind person could use his/her own, personalized long cane. In this approach however, the accuracy of the system was not satisfying, because of the walking speed (4.5 km/h) and the various step width of the blind test person. The hit rate was very low (33%); so, on a path with twelve ITs only about four were correctly recognized. To improve the accuracy we decided to test a new setup with a spot arrangement of many tags instead of only one single tag (see figure 2). This Tag Array (TA) was to improve the hit rate of a tag location. In the network graph such a TA is handled like a single tag-spot.

To test various group arrangements, a test route with five TAs was created. The test users had to walk randomly along the test route with the FM-RFID-reader and the hit rate was measured. The average hit rate of a single tag was only about 10 percent. With a TA of three or four tags the average hit rate was nearly 40 percent (see table I).

To increase the hit rate, we tested different tags on their reading range. The result of these tests was that the tags used in Sesamonet (Texas Instruments 134.2 kHz RFID Transponders, type RI-TRP-R9QL-20) did not have a sufficient reading range (approx. 11 cm). The only tag with a plausible reading range (approx. 30cm) was the cylinder tag (Texas Instruments, 134.2 kHz RFID Transponders, type RI-TRP-R9TD). The first test in a real setting was prepared using this tag.

B. User test Suedtirolerplatz, Vienna

In January 2011 the first indoor test at Suedtirolerplatz was carried out with all the project members and some foreign observers. For the test we wanted to build in ten TAs in a 2x6 grid in order to achieve the highest hit rate. Since the test was done in a real environment, we decided to use only six tags with a distance of 20 cm between them for every TA (see figure 2) in order to minimize the inconvenience for the other public transport users. The TAs were located on one side of the TGS and were always placed 130 cm away from a tactile POI. In total, seventy two cylindrical transponders were built in and closed with cement (residual depth 0.8 cm).

C. First results at Suedtirolerplatz, Vienna

In the first real test, four blind men, aged between 35 and 60 years, tested the system. All of them were able to quickly install, launch and control the software. They all were able to mount the FM-RFID-reader on their shoes and connect it to the phone via Bluetooth. All of the test persons chose their destination in the software program without any support from an extra person. All of the men were able to reach their chosen destination with the help of the TGS, the FM-RFID-reader and software. One test person walked too quickly for the speech software, thus missing his turn. The software noticed this immediately, because the next unique tag number did not correspond with the expected tag number. The software recalculated the route and told the test person to turn around. After this routing correction the test person found his destination without any other difficulties.

In total, seventy two tags were able to be read (12 x 6 tag arrays). All of the TAs were read with both the FM-RFID-reader and long cane RFID-reader. Just two or three single tags per TA were read with the FM-RFID-reader. When using the long cane RFID-reader, maximal two single tags per TA were read at a swinging speed of the long stick of about 15 km/h and with an angle of 60°(see table II).

The most important deficit of the INS "ways4all" is the short reading range of the LF tags. The ways4all-software and the Bluetooth connections work in a convincing manner.

The decision for a passive low frequency system was made in 2008 based on the following considerations: no battery, low maintenance, simple system integration, low priced tags, works well with water on top (especcially compaired with RFID-tags

TABLE II
HIT RATE TEST METRO STATION

Tester	Age	Speed (km/h)	Long cane RFID reader hit rate (all 72 tags=100%)	FM-RFID-reader hit rate (all 72 tags=100%)
User 1	35	2,3	23,6%	40,3%
User 2	39	1,8	26,4%	34,7%
User 3	44	3,0	16,6%	26,4%
User 4	60	1,5	33,3%	57,7%

with a higher frequency), works imbedded in concrete and is not influenced by magnetic fields.

To increase the reading range, the project team is developing new passive LF tags. At the moment fifteen prototype tags have been made and have been tested successfully in the laboratory surroundings. The first field test will take place in summer 2011.

V. SYSTEM COSTS

One of the main aspects for this INS is the cost / benefit analysis. The costs are important for two groups of users: the users of the navigation software and the providers in public transport and cities. The benefits of this system cannot be calculated in monetary revenues, simply because freedom of travel and the feeling of being self-determined cannot be expressed in values. The costs for the users of the software are very low. The system uses a normal smart phone (Nokia E52: EUR 230), the FM-RFID-reader (EUR 286) or long cane RFID-reader (EUR 1.051). The cost of the system itself can be divided into two phases: the building and the operating phase. The cost of one tag is around EUR 20. The next step is filling the database; depending on the size and complexity of the building, it will take a few days work. If an existing area is to be supplied with this system, the cost are higher than implementing this system during the construction phase. The total cost of implementing this system in an existing area of $2000m^2$ will be around EUR 20 000; in a new area the cost will be 50% less (EUR 10 000). In the operating phase everything is automatized which will have as low a cost operation as possible.

VI. CONCLUSIONS

A cost effective RFID-based mobile INS for visually impaired and blind people has been developed.The main advantages of the application are: the low cost and wide accessibility; the simplified and intuitive user interface; the communication with different means of public transport; audio-enabled navigation; no absolute coordinates or building plans are required; hardly any extra equipment is necessary (just a foot-mounted RFID-reader); the system is expandable to outdoor navigation and is made accessible for other user groups.

The first result of this project is to pinpoint the fact that it is not easy to choose the right types of tags for indoor navigation, because not every RFID-reader can be used. Furthermore, the reading range of the different tags is lower than expected. The reading range of the passive RFID-tags varies from two to thirty centimeters; in the final functionality a reading range of at least sixty centimeter is needed. An FM-RFID-reader is preferred by the visually impaired and blind people. A blind person wears out two long canes a year, so the cost for the equipment would be EUR 2 102 a year whereas the FM-RFID-reader can be used for many years. The navigation system will be expanded to outdoor navigation, inertial navigation, and communication with real time public transport information and will be made accessible for other user groups, like wheelchair users, the physically impaired and all other travellers.

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