RFID Information Grid and Wearable Computing Solution to the Problem of Wayfinding for the Blind User in a Campus Environment

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Abstract

We describe a navigation and location determination system for the blind using an RFID tag grid. Each RFID tag is programmed upon installation with spatial coordinates and information describing the surroundings. This allows for a self-describing, localized information system with no dependency on a centralized database or wireless infrastructure for communications. The system could be integrated into building code requirements as part of ADA (Americans with Disabilities Act) at a cost of less than $1 per square foot. With an established RFID grid infrastructure blind students will gain the freedom to explore and participate in activities without external assistance. An established RFID grid infrastructure will also enable advances in robotics which will benefit from knowing precise location. In this paper, we present an RFID-based information grid system with an RFID reader integrated into the user's shoe and walking cane with a Bluetooth connection to the user's cell phone. To assist in navigation, user feedback and communication via a NAVCOM belt worn around the user's waste is introduced that features a sonic range finder and a series of pager motors for distance feedback and a form of vibrational Braille. An emphasis is placed on the architecture and design allowing for a truly integrated pervasive environment with minimal visual indicators of the system to the outside observer.

Keywords: *Blind navigation, proximity sensing, RFID Information Grid, Wearable systems.*

1. Introduction

Blind students are at a tremendous disadvantage when they arrive on a college campus, where they must somehow face the challenges of being an incoming freshman who can not find their classrooms, meet with academic advisors, or find the line to stand in during the professor's office hours to ask a question about homework. It is a daunting task that places an immeasurable burden on the hopes and dreams of a future productive member of our society. Even in an ideal academic setting in which a university has unlimited resources to minimize classroom challenges, the blind student will miss out on numerous educational and experiential opportunities outside the classroom. The blind student should have the freedom and the ability to locate and participate in student meetings, meet friends at the Student Union for a cup of coffee, attend a rally on the political topic of the day, go to the gym for a workout or walk to the campus ice cream shop.

The following simple statistics and facts put the blind student dilemma into perspective and set new priorities and challenges for our educational systems.

- Number of blind persons in this country: 1.1 million [1]
- Number of blind school age children: 57,425 [2]
- Number of blind seniors, 65 and over: 787,691 [3]
- Projected number of seniors who will be blind by the year 2015 -1.6 million, and by the year 2030-2.4 million [4]
- Number of working age blind who are unemployed: 74% [5]
- Estimated annual cost of blindness to the federal government: $4 billion [6]
- Lifetime cost of support and unpaid taxes for one blind person: $916,000 [7]

The problems in user location detection for the blind students are complicated by the challenges of resolution, accuracy, privacy, user orientation and reliability. The resulting solution should adhere to the Principles of Universal Design[8]. *Equitable Use:* The design is useful and marketable to people with diverse abilities. *Flexibility in Use:* The design accommodates a wide range of individual preferences and abilities. *Simple and Intuitive:* Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level. *Perceptible Information:* The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities. *Tolerance for Error:* The design minimizes hazards and the adverse consequences of accidental or unintended actions. *Low Physical Effort:* The design can be used efficiently and comfortably and with a minimum of fatigue. *Size and Space for Approach and Use:* Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

This paper presents a solution to the problem of wayfinding for the blind on a college campus. Our solution addresses the following challenging requirements:

- The user must be informed of their location in the room within the context of the room, or outdoors within familiar contexts such as named intersections, bus stations, and building names.
- The user must be provided feedback as to the current user orientation.
- The system should be able to report the location, distance and direction of items in the room such as office equipment, furniture, doors and even other users.
- It must be a reliable system that minimizes the impact of installation and maintenance to the building owner
- It must provide absolute location with no possibility of error from outside influences
- The system should not be obvious to an external observer
- The proposed solution should meet or exceed the standards proposed in the Principles of Universal Design.

We present the information grid concept and the design of a wearable system that utilizes an RFID based information grid to achieve reliable wayfinding and proximity sensing for blind users. We present detailed implementation of the system and its tactile user interface. We also provide experimental analysis of the usability of the system by various user groups with varying walking pace.

2. Requirements and Design

Our framework for the solution meeting the Principles of Universal design is as follows. An information grid based on passive, low-cost, High Frequency RFID tags is installed under the flooring and used to convey precise location and detailed attributes about the surrounding areas. In the university environment, RFID tags can be installed along outdoor pathways, in building hallways and in rooms. By storing all information in the RFID tags about the surrounding space, no external dependencies to spatial databases is required or the need for wireless infrastructure to support connection to the database. The base RFID information grid can provide the foundation of precise indoor/outdoor location for the blind user, aid in automated navigation for electronic wheelchair users, and supports service robotics that can use the RFID tags to determine exact location.

The central computational system for the blind user should be based on commodity electronics such as advanced cell phones that support Bluetooth and Java programming for application development. Ideally, text-to-speech and voice recognition could provide a possible user interface but current state-of-the-art technology is not available at commodity pricing. It is anticipated that this will become a viable option in the future and can serve as an additional user interface into the system. The Siemens S65 cell phone meets the base criteria of Java MIDP and Bluetooth support for under $200 inclusive of a service contract

The user sensor network is designed to run on Bluetooth using the Serial Port Profile (SPP) for wireless communication to wearable peripherals. To accommodate the blind and the visually impaired, a small RFID reader from Skyetek is integrated into a walking cane and also a shoe with SPP communication using a Bluetooth module from connectBlue. The unit cost of each Bluetooth RFID combination reader is $170.

To minimize the dependency on or augment the use of the walking cane for object detection, a NAVCOM belt was designed with an ultrasonic range finder integrated into the belt buckle using a Java based embedded system for control. A pager motor is placed every 25 degrees along the circumference of the worn belt. The appropriate motor will vibrate based on the distance of objects located in front of the user. As an object moves closer, the distance is measured and the appropriate pager motor is activated so the user feels the scale of the distance to the detected object along the circumference of the belt. This provides additional information to the blind user to detect location of walls, objects along a path or other people in crowded areas often found on college campuses. The pager motors also serve as an alternative communication interface for vibrational Braille. Three pager motors along the left side of the waist represent the left three dots of Braille and three pager motors along the right side of the waist represent the right three dots of Braille. A Bluetooth SPP connection allows the MIDP application on the cell phone to communicate navigation information derived from the RFID tags or other forms of electronic messages such as SMS, Caller-ID, email or other mobile productivity applications. The unit cost of the NAVCOM belt in limited quantities is under $200.

We have introduced the concept of using RFID tags as a method of locally storing data about the environment where the information is relevant (in-place storage of location-based information). In the following sub-sections, we discuss the specifics of the RFID tags, the data protocol for storing information and the user interface. We refer to the target system as the RF-PATH-ID system. It is also important to recognize that a blind individual is not always in the need of determining their current location at every step. If the blind individual is in a space familiar to them then they would have little need for precise location feedback. The use of the NAVCOM belt gives additional feedback on the location of fixed and moving objects.

2.1. Indoor Navigation Infrastructure

A single passive RFID tag represents a single grid point in the system. If resolution of one foot is required this would add a material cost of $120.0 to a 10 x 12 foot room or one dollar per square foot. Carpet manufactures could integrate the RFID tags as part of the weaving process or the RFID tags could be integrated into a thin layer of material that is applied under the carpet or hard surface flooring. Rooms that have existing carpeting could be easily upgraded by rolling up the carpet, applying the RFID flooring material and then reinstalling the existing carpet. In the case of tile floors it may be possible to insert RFID tags by removing the grout at tile intersection points and then reapplying the grout.

For pathways that provide travel from location-to-location such as sidewalks, hallways, stairs, etc. RFID tags can be located on the edge of the path. This allows for lower implementation costs because a grid is not required to indicate position. The path tends to be narrow and well defined that only a single line of RFID tags are required. The tags would indicate position and describe major locations such as building names, room numbers, bathroom locations, type of door and description of stairs. This would be a modern data extension of Braille that is electronically readable by a sub-system as part of the navigation process.

2.2. Outdoor Navigation Infrastructure

The laundry industry has developed an innovative RFID tag to allow the combining of laundry loads with an RFID tag placed in each item of clothing. The RFID tag is sealed in a small plastic housing the size of a quarter and is waterproof and heat resistance. The use of laundry tags provides a low cost and dependable solution against the harshness associated with outside installations.

Outdoor campus navigation is primarily concerned with route information from origin to destination. This limits the amount of information that needs to be stored or conveyed to the end user and the location of RF-PATH-ID tags to established routes. When a sidewalk is bordered by grass the RFID tag can be installed along the edge of the sidewalk aligned with the sidewalk joint or crack serving as an indicator to the end user that a tag is located on the corresponding edge. The user would need to move the RFID reader over the edge to determine location and additional route possibilities.

The outdoor RFID tag could also be used in metropolitan areas to indicate location, surrounding street names and addresses by mounting to concrete sidewalk or any road surface. The tags could also be placed on road markers allowing an RFID reader installed in an automobile to determine precise location in metropolitan areas where GPS does not work. For example buses used in public transportation are required to announce via voice the upcoming bus stop as an ADA requirement for the blind. This is difficult when the location of the bus is hard to determine. By reading RFID tags along the road or at bus stops, the precise location of the bus is known and an audio event triggered to announce the next bus stop.

2.3. Room and Path Mapping

Once the grid or path of passive RFID tags is installed, a space survey is done to determine the precise coordinate of one RFID tag. The features of the room are located based on this one fixed point or anchor. With a layout and description of the room, each RFID tag is then programmed with position information and descriptions of objects in the room. The surveying costs are common to all system implementations attempting to establish location sensing. The storage capacity of the RFID tags is limited so a uniform method to describe room attributes as they relate to the location of the RFID tag is required. RFID tags located in a traffic pattern leading to a door would provide information related to the door location, type of handle and opening direction. Storage of information in the RFID tags based on their location allows for a flexible system with absolute positioning, and at the same time, protects the privacy and location of the user because external links to a central server are not required.

The end user would interact with the system through an RFID tag reader integrated into a walking cane, an attachment to a shoe or a hand held device. The user can quickly determine his/her location by passing over an RFID tag. To determine orientation, the user would extend their foot or cane forward to neighboring cell which would provide relative directional information. This information can then be integrated with a PDA or smart phone to the user location, orientation and description of the surroundings. If detailed information about the room is available in a central system the smart phone can send a location query for a room based on current location or a potential location in the future. This information can then be used by location based software on the PDA to provide value added services to the blind user.

2.4. RFID Technology Options

RFID covers a range of RF frequencies with specific uses based on the frequency and packaging. Multiple manufactures have developed proprietary and standards based communication protocols. Passive RFID tags do not have a built in power supply; they are powered entirely from the RF field produced by the RFID reader antenna. It is this close coupling which limits read range to 3-6 inches unless the RFID reader is using a very large antenna and strong RF signal. The High Frequency tags offer the advantage of storing up to 10K bits of data and are paper thin. The UHF tags have improved read range which is important in supply chain management and offer a one-to-one substitute for the barcode with a 12 byte identifier. The UHF tags are favored by retailers like Wal-Mart to be integrated into future retail products.

The RFID tags selected for this project are manufactured by Texas Instruments and operate at 13.56 MHz in the High Frequency category. The TI tags support storage of 2000 bits or 250 bytes and come in a variety of sizes and form factors with a data retention time > 10 years. The larger the surface area for the tag antenna the better the read range. The cost of the TI ISO-RFID tag in quantity is around $1 per tag with lower unit costs in the future as volume increase and manufacturing costs are reduced. The TI ISO15693 Transponder can be packaged as part of a label for quick installation or in a PVC or plastic housing for protection.

2.5. Mobile Software Platform

The Java 2 Micro Edition (J2ME) Mobile Information Device Profile version 2.1 (MIDP 2.1) was selected as the platform for software implementation to maximize the number of PDAs and cell phones that can be used. MIDP 2.1 is also chosen because of its support for audio, which is needed for playing voice prompts. CLDC 1.1 is required as it supports floating point calculations which are required for calculating distance and direction. In MIDP 2.1, Bluetooth is supported which provides wireless communication to Bluetooth enabled devices. The SPP Bluetooth interface enables communication between the embedded devices via the serial port of the embedded device. The embedded devices are unaware that serial communication is taking place via Bluetooth.

2.6. RFID Reader

The Skyetek M1 and M1-Mini where selected as the RFID readers in this research because of their small size. Both boards come with a built in antenna. The specifications state that the read range of the M1 is 75mm with the internal antenna and 150mm with the EA1 external antenna when reading credit card sized RFID tags. The M1-mini has a read range of 70 mm with the internal antenna.

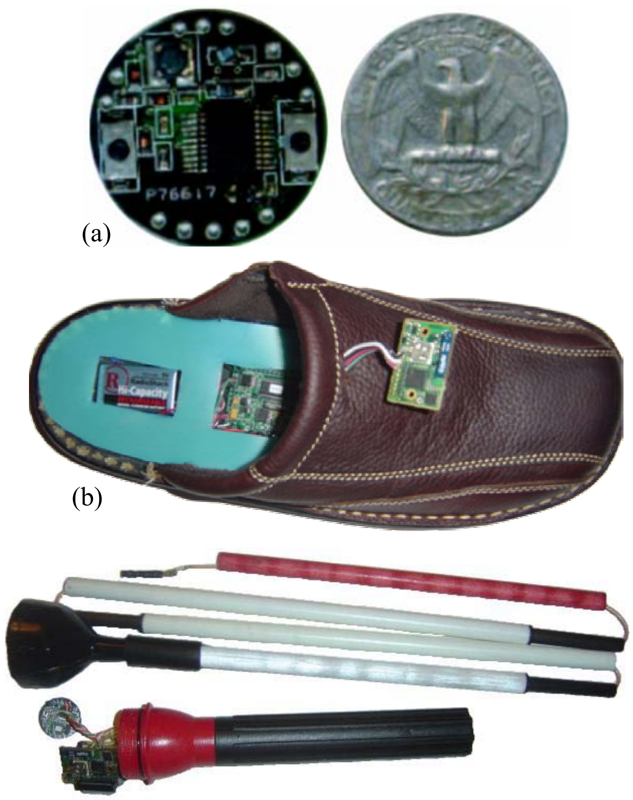

Figure 1. (a) RFID Reader, (b) In-shoe reader design, (c) In-cane reader design (Photos not the same scale)

2.7. Data Encoding on RFID Tags

A variety of data formats and data elements can be achieved with 2000 bits of information storage per ID tag. At a minimum, each tag will store its world coordinates. Latitude and longitude can be used for long term data services and global positioning. This may create an accuracy and survey problem and potential added expense when laying out tag locations. This problem also exists for a coordinate system that is accurate within a building; using latitude and longitude communicates accurate position information with minimal local error.

We will investigate information-to-tags distribution schemes whereby detailed information about objects and artifacts in any location can be fully identified despite the storage limitation. We will exploit redundancy in storing key reference artifacts in a room at key locations. This will allow the RF-PATH-ID system to learn quickly about the position of major elements in the room. For instance, the room needs to have its inventory stored at tags concentrated near entrances to the room. The position of objects can be stored as relative to the absolute position of the tag that contains the information. This provides for conservation of storage bits by reducing the length of data that needs to be saved but still maintains resolution.

One design goal would allow for independent and anonymous use. This eliminates the need for a central server to provide translation or missing information. It is also important to recognize that the future uses and objects to describe are unlimited which makes data formats and codes very important. To achieve such independence and to enable localized processing and interpretation of sensed information, a self-describing data representation is sought. This provides a clear indication that XML could be a strong candidate format. While XML will allow for maximum data flexibility, this will be achieved at the expense of very verbose and overly descriptive coding. With a limited storage of 250 bytes per tag, an XML format would not allow for maximum data storage.

A hybrid XML data format that uses dictionary tags to represent the data grammar of the system would provide a good compression rate in a hierarchal parent-child format. This format will be referred to as CML for Compact Markup Language. Allowing for a dictionary of 250 elements and occupying one byte can provide a good compression and still allow for the verboseness and hierarchical structure of XML. If the dictionary exceeds 250 elements then the primary dictionary can be reduced to 0-127 and a two byte allocation could be used for dictionary values greater than 128 at the expense of an extra byte for dictionary values greater than 128. Data elements that do not contain a dictionary definition can use an ASCII representation.

The following XML represents a typical data set stored on an RFID tag and the non-white space length is 251 bytes. The CML format compresses down to a length of 117 bytes enabling approximately six room objects to be stored per tag with maximum flexibility in the type of data that can be stored.

```
<tag>
  <location>
    <latitude>1234.5678</latitude>
    <longitude>5678.1234</longitude>
  </location>
  <object type="chair">
    <positiontype="delta">10 10</position>
  </object>
  <object type="table">
    <position type="delta">10 -10</position>
  </object>
 </tag>
```

Further compression can be achieved by using Huffman encoding for variable length encoding based on the frequency of each data dictionary value. The XML tags used for open, close and attribute would have a very high frequency and would be reduced to a 2 bit value. The numeric characters 0-9 would also have a high frequency and could be reduced to a 3 or 4 bit value. Like the common dictionary to represent common objects needs to be known in advance the Huffman encoding would be based on a global tree structure common for all encodings. To evaluate the potential compression of Huffman encoding a sample XML doc was used that contains 14 objects and there position relative to the RFID tag. This XML doc was used to generate a Huffman encoding tree based on the frequency of the CML data bytes. This common histogram tree is then used to compress a series of CML data descriptions with the addition of one room object per iteration. Figure 2 shows a 14 object XML representation is 869 bytes and the CML size is 465 bytes and the Huffman encoded version of the CML file is 254 bytes. By using Huffman encoding it is possible to store on a single 250 bytes tag the latitude and longitude of the tag and the relative location of 14 objects in the room. The compression from XML to CML results in a compression ratio average of 1.83 with a standard deviation of .025. The compression from XML to Huffman encoding results in a compression ratio average of 3.31 with a .10 standard deviation. By using CML and Huffman encoding to represent an XML data structure it is feasible to store verbose flexible descriptions and locations of spatial objects versus a flat and inflexible data representation of the objects.

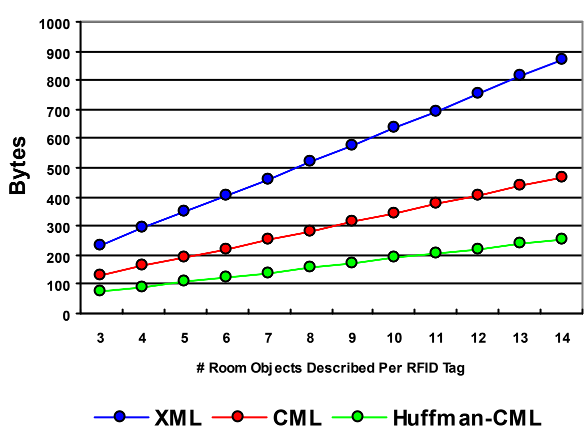

Figure 2. XML vs CML vs Huffman encoding efficiency

2.8. NAVCOM Belt

One of the key elements of navigation for a blind user is the use of the cane to detect objects in the walking path. A navigation belt using ultrasonic range finder was developed to decrease dependency on using a cane in tight spaces such as hallways, classrooms and labs. The Devantech SRF08 Range Finder has a range of 3cm to 6m and the ability to detect the distance of up to 16 objects in its field of view. The range finder interfaces to the Systronix JSTAMP embedded controller via the IIC standard bus. The “Optec Disk Motor” pager motors are controlled by a port expander (PCF8574AT) on the IIC bus connected to a high voltage, high current darlington array (ULN2003). A total of 14 pager motors are used and placed every 25 degrees around the circumference of the belt.

The control software written in Java collects the distance to objects and activates the corresponding pager motor to indicate the distance to that object. This allows for constant user feedback of objects in the walking path by using vibration. This allows for assisted navigation in hallways and rooms without the use of a cane. This can also aid in navigation outside to detect other people walking along a path, fixed or unexpected obstacles.

An additional function of the NAVCOM Belt is to provide an alternative communication interface for the RFID navigation system. The NAVCOM Belt has a Bluetooth SPP interface that allows the software application running on the Java MIDP enabled phone to send vibrational Braille instructions to the belt. This allows the RFID-PATH-ID system to function without the use of audio or voice prompts that would interfere with the users hearing, a critical sense for the blind.

Additional research will be conducted to test the effectiveness or words per minute using vibrational Braille. To compensate for multiple belts being used by different users in the same space a form of carrier sense multiple access with collision avoidance (CSMA/CA) can be used to detect the presence of other ultrasound signals before transmitting.

Figure 3. The NAVCOM wearable ultrasonic range finder

3. Proximity Sensing

Knowing the location of objects in a room via absolute coordinates is an important design requirement. It is important to determine user orientation so navigation to the object can occur. In order to determine orientation or angle relative to the axes, the user needs to touch two points with a frame of reference to the user body. If the user sweeps left to right touching two points, the coordinates of the two tags can be used to determine the midpoint. The perpendicular to the midpoint would indicate direction and orientation. Given this orientation, the system can calculate direction and distance to objects in the room. The spacing and distribution of the tags will play an important role in determining the accuracy of the system.

The reading of the RFID grid should have minimal impact on how the user walks through the space. This creates a requirement that the tags must be read as quickly as possible, when the reader, which is attached to the shoe or walking cane, is moving. The RFID tags are in a powered off state and must be charged in the presence of an RF field and the unique tag ID returned. The reader then issues a select command with the address of the RFID tag that indicates to all other RFID tags in the RF field that they should not respond to any of the following commands. This design allows a large number of retail products or merchandise to be in close proximity of each other and one tag at a time can be read once an RF inventory is taken of all available tags located in the RF field. The command execution time for tag selection is approximately 140 ms and is required to issue any subsequent read commands.

The 13.56 MHz signal from the reader has the commands to that tag modulated in the RF. The tag must then retransmit the response to the command on the same signal. If the command to read 10 bytes of data is issued, the tag must access its memory, retrieve the data and modulate it back to the reader. The response time will vary depending on the amount of data to be read. This has a direct impact on the amount of time it takes for the reader, which is moving, to have the tag in its RF field of view and get an accurate read. The graph in Figure 4 shows the read times for four tags of varied sizes versus the amount of data to be read. No major difference could be detected between the RF tags response time. The increased surface area helps with read range but appears to have no impact on response time. However, the larger the tag the bigger the read range which would make a difference on the read window for the moving RFID reader.

The Skyetek reader has a limitation that does influence read times. The microprocessor on the reader has 80 bytes of available ram; the largest command it can send and receive is 80 bytes minus 16 bytes for command structure leaves 64 bytes of data. To read 71 bytes of data requires two reads one for 64 bytes and one for 7 bytes. The overhead of issuing multiple reads does not appear to cause a major time penalty as we go from 10 to 252 bytes. The initial overhead of setting up the first read and subsequent reads is not linear. To read 252 bytes still takes 900 ms with 140ms setup time to select the tag. Changing to a reader that can support a single read of 255 bytes will improve performance which is important to achieve a full read on a moving reader. The alternative is to have a learning mode in which the RFID reader/software detects a new tag and issues an audio prompt for the user to stop and read the tag. Additional research needs to be conducted to test the amount of time it takes the user to find the tag. After the RFID tag is found, the maximum read time is under one second and once this data is read from the tag, it can be stored as part of the application so that a full read in the near-future is not required. The Tag-it protocol from TI supports the ability to read a tag without selecting it which would save the 140ms required to do a select. Utilizing the current implementation it is possible to fully read a tag in under a second with room for improvement by changing readers or tag types.

It would not be practical to ask the user to walk in a manner that would allow the reading of only one tag every second. The primary design for the RFID tag in the retail industry is to read as many tag identifiers as possible in the shortest amount of time. The statement that 50 tags per second can be read at once refers to reading of the unique 8 byte identifier found on every tag. Once the 8 byte identifier or tag address is known, it is then used to issue commands directly to that tag. This fast read time and unique identifier can be used to determine location along a known path.

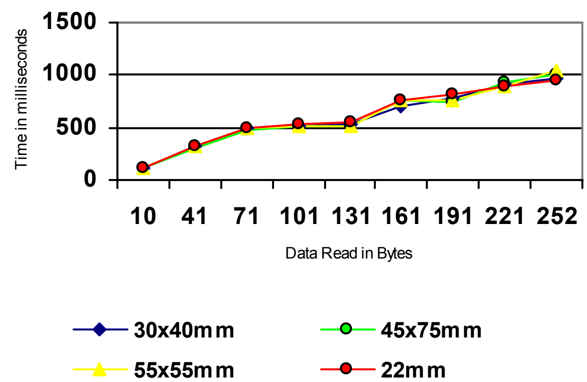

Figure 4. RFID Read Rates

The graph in Figure 5 indicates the number of tag addresses read along a 20 foot carpet path with a 55mm x 55mm tag placed every 12 inches. The tags were placed on the bottom side of the carpet and no visual or audio indicators were provided when walking along the path. Before the first step is taken the RFID reader shoe is aligned with the first tag. This is used to indicate the start time while the last tag at the end of the path is read to indicate the stop time. Two walking paces were tested to determine the impact of a normal walking speed and a fast pace in reading of tags. The maximum number of tags that can be read along the path is 20, one per 12 inches. Read error is introduced by not walking a straight line because no feedback is given if a tag is being read.

The average walking speed for a younger walker is 4.95 feet per second [9] so it should take approximately 4 seconds to walk 20 feet. The first group of five walking tests averaged 24 seconds with an average of 17 tags read. The second group of five walking tests averaged 9.6 seconds with an average of 10 tags read. The second walking group was at a quick pace so the difference of a 4 second time and 9.6 second time could be related to the standing start and stop time over a short distance. The initial results of reading a tag every two feet at a quick walking pace without any form of feedback is promising. The internal antenna of the Skyetek reader was used for this test. Additional work needs to be done to integrate an antenna along the diameter of the shoe to improve the read range and coverage area. The study needs to be expanded beyond technical validation to include visually impaired and blind users to allow for comparison of overall travel speed in familiar and unfamiliar locations. Results could also be improved by including an RFID reader in each shoe. Integrating the RFID antenna/reader into the walking cane also provides additional reader input with the ability to cover a larger area by moving the cane from left to right while walking.

Figure 5. Testing the effect of pace on number of read tags

The current implementation has the RFID reader integrated into the base of the shoe to minimize the distance of the antenna to the RFID tag. It is also possible to use an external antenna that is installed along the outer edge of the show to maximize read range. The electronics could then be placed in a small enclosure attached to the shoe. This provides for easier maintenance and the ability to use with multiple shoes. It is also possible for a truly pervasive experience to have the electronics manufactured into a custom shoe. The only design requirement to maximize read range is to have the antenna as close as possible to the floor.

4. Related Work

Numerous papers have been written on indoor location sensing using various forms of triangulation or signal strength pattern matching [10,11]. They each have an infrastructure dependency on RF transmitters that are subject to error based on changes in the space and multi-path reflection problems. In controlled environments results are good but it is difficult to detect error conditions which impact the reliability of the system for the blind user.

The High-Density RFID Tag Space [12] uses active RFID Tags on a grid density of 1.2 meters. Active RFID tags have a battery power source which allows for a stronger transmission signal for each tag. With each active tag transmitting its ID, the position of the user is determined by averaging the location of each tag detected. The transmitted ID of each tag is used to lookup the known coordinates of each tag. Determining position by the active RFID grid is only a portion of the research with the main focus of the paper on using Finger-Braille to communicate navigation commands to the Deaf-Blind user. These design attributes makes it expensive and not practical to scale this solution beyond a test environment.

Ross and Blasch, in 1996 and 1997 introduced the concept of “Cyber Crumbs: Development of An Outdoor Orientation Infrastructure”, and “Cyber Crumbs: Subject Testing Indoor Orientation Aids” [13]. The Cyber Crumb concept centered around using a beacon at key locations along a path that could provide the user feedback on changing direction along a path. Comparisons are made of systems using GPS/Digital Compass, outdoor IR beacons, passive and active RFID systems and the Locust IR system developed at MIT Media Lab [14]. The GPS based system proved difficult because of the overall location readings varied by 25 meters and the negative impact of large metal objects on the accuracy of the Digital Compass. IR Beacons with a transmit range of 85 feet were tested to assist with blind users walking in the direction of the IR Beacon.

RFID and Locust [14] were used indoors to assist with navigation. The antenna was integrated into the cane and using an audio tone the user would walk towards the tag based on signal strength and then when in range of less than 10 inches the tag would be read for location information. An attempt to use active RFID tags was not successful because the metal studs in the walls propagated creating phantom signals that made it difficult to detect the location of the tags.

Twenty visually impaired or blind users tested the system. The RFID system produced no fatal errors in navigation where the locust system produced three fatal errors. No reasons were given as to why the locust system produced fatal errors. Travel time was 30% less using locust versus RFID because the user did not need to find the RFID tag to read its information. The wide read range of the locust system made it easier for the user to navigate.

Drishti [15,16] uses a combination of DGPS for outdoor navigation and ultrasound positioning devices for indoor navigation for the blind. It targeted campus environments and aimed at providing precision navigation on “walkable” areas outdoors, and on supporting on-demand querying of proximity information. The shortcomings of DGPS are well documented including its size and weight, and when the user does not have a clear view of the sky. The utility of the DGPS approach is also limited due to signal barriers such as large trees and tall buildings.

5. Conclusion and future work

The concept of setting up an RFID Information Grid in all buildings is technically and economically feasible. The barrier to entry for this technology is low as a result of leveraging the commodity pricing and innovation in the retail sector. This permits the adoption of the RFID Grid to be localized in small businesses, large corporate parks, government buildings or college campuses. Such grid will be capable of removing barriers for the blind user to fully integrate into their environment. Our grid approach is based on mature technology and is economically feasible that we believe it could become an ADA mandate for all future building construction with demonstrated success on a college campus and other public/private venues.

With an established framework for reliable and accurate location sensing, the challenges of communicating an awareness of surroundings need to be addressed. The blind user is at a disadvantage in operating standard user interfaces of cell phones and PDA's. This forces a rethinking of how the blind user interacts with potential pervasiveness of technology. Text-to-Speech and voice recognition can play a significant role in solving these problems. Mapping GIS information onto the RFID information grid in a manner that provides the user the information they need when they need it represents a significant challenge. We are excited about the potential of providing a reasonably priced and reliable solution to location awareness as this becomes the enabler for innovation in pervasive computing.

As part of future work, the core application responsible for assisting with wayfinding will be further developed. An automated robotic platform will be designed and constructed to address the labor costs of installing the RFID grid, surveying the location of objects and storing spatial information in the RFID grid.

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References

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[2] APH, Federal Quota Census of January 1998

[3] Chiang, et al., 1992

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[5] AFB Sept./Oct. JVIB Kirchner & Schneidler, 1997

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