BlindAid: An Electronic Travel Aid for the Blind

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Contents

Chapter 1

Introduction

The goal of BlindAid project is to develop navigational assistance technology for the blind or visually impaired. Specifically, we seek to develop a portable Electronic Travel Aid (ETA) for visually impaired users, along with the accompanying radio frequency identification (RFID) localization infrastructure used to equip buildings.

In our research through literature, interviews and ethnographies with the visually impaired and rehabilitation service workers, as well as interviews with various researchers we identified that one of the major problems the visually impaired experience is trouble with indoor navigation in unfamiliar buildings. Imagine the wide open spaces in an airport concourse; even if there are braille signs at the counters, the blind may not be able to find them!

There has been little done in regards to indoor navigation in current assistive technologies, known as Electronic Orientation Aids (EOA), possibly due to high cost for instrumentation and limited capabilities. BlindAid's goal is to break down these barriers by introducing an EOA system which is relatively inexpensive for both the blind and the businesses that equip their buildings. We propose using RFID tags to set up a location–tagging infrastructure within buildings such that the blind can use an RFID equipped ETA (such as a cellphone) to determine their location as well as software that can utilize this localization data to generate vocal directions to reach a destination.

Having done the background research and developed the BlindAid Navigational Assistance idea in a previous semester (`http://www.cs.cmu.edu/~phri/BLINDAID/index.shtml`) we decided to continue pursuing this idea through the V–unit by prototyping the device to determine whether BlindAid is technologically and commercially feasible and whether it can improve the experience of the blind user. Results from both phases of research are presented in this report.

Chapter 2

Motivation

Imagine walking into an unfamiliar airport. The places we have to search for, airline ticket counter, security check-in, boarding gate, are difficult to find even with signs. Imagine how much of a challenge this would be if you cannot even see the signs!

Everyday situations present similar challenges. While shopping malls often have building maps, they are usually stationary displays that are useful only when one can locate and read the display. Many medical and academic buildings lack even this kind of navigation assistance. Challenging for a sighted person, the task of finding a way in such a building for an unassisted person with visual impairment becomes nearly impossible.

According to the 2002 U.S. Census Americans with Disabilities report [1] approximately 7.9 millions individuals 15 and older have difficulty seeing, including 1.8 million individuals that are unable to see [2]. Guide dogs, extensive training, and gradually appearing GPS navigation devices provide the visually impaired with some degree of independence in unknown environments, though most effort seems to be aimed at increasing outdoor mobility. The problem of indoor navigation remains largely unsolved. It should be noted that mobility and navigation are two distinct problems. Outdoor mobility can present more potential dangers to blind travellers because obstacles and hazards such as motor vehicles and dangerous terrain can be life-threatening. Since indoor hazards tend to be far more benign, the safety issues addressed by typical travel aids are less useful indoors. Navigation tends to be more difficult indoors because the environment is so homogeneous. Rather than searching for unique features, a traveller needs to count doorways and intersections or find some other way to distinguish between largely identical features such as offices or doorways.

Chapter 3

Related Work

The problem of navigation assistance has been addressed in academia, primarily from the angle of human-computer interactions, and in the industry, by proposing some commercially viable systems that utilize recent advances in mobile device and sensor technology.

In particular for outdoor navigation the availability of GPS-compatible cell phones and PDAs prompted appearance of a number of software products, some of which have accessibility features making them potentially suitable for the blind and visually impaired users. An example of such software that provides verbal instructions is CoPilot Live [3]. For more references to we refer the reader to the insightful review at [4].

The infrared based Talking Signs [5] has been extensively tested and proved to be helpful, in particular for crossing intersections. This system uses directional infrared transmitters mounted in the environment, and a handheld receiver with a speaker.

For indoor navigation a variety of alternatives to GPS have been proposed.

Marco and LocustSwarm [6] use mounted IR transmitters and handheld (or, in case of LocustSwarm, wearable) IR receivers to determine localization. Verbal Landmarks [7], however, uses a handheld receiver to detect messages transmitted from induced radio signals, which are omnidirectional. When detected, receivers picked up digitally recorded voice messages on an unused FM band.

Some of the barriers that prevented these products from wider acceptance include:

- High cost
    - For instrumenting the environment with transmitters
    - Active transmitters require installation and maintenance
    - For users or companies to purchase handheld receiver
- Limitations in capability and usefulness
    - IR requires line-of-sight
    - Active transmission requires power supplies and maintenance
- Limited user studies to prove effectiveness, and thus provide incentive for implementation

From looking at these past attempts, we wanted to focus on a product that is low in cost for both the companies equipping their buildings and for the blind users. The result was the decision to use RFID tags which are low in cost for large quantities, a compact RFID reader, as well as using cell phones as the handheld device. Since the large fraction of the cost is in the receiver and user interface hardware, cell phones (which most blind travelers carry anyway) would be a suitable platform to deploy low-cost navigational software on to eliminate the need for a specialized handheld device specifically for this one application.

Use of RFID tags has been proposed for indoor navigation assistance in earlier works (e.g. [8]). However, to the best of the authors' knowledge there is no published user studies that evaluate such RFID-based indoor navigation systems and their user interfaces. This study is aimed to fill this gap.

3.1 Interface

Use of verbal commands for blind pedestrians have been studied in [9]. This work enumerates the possible navigational choices that face a pedestrian in outdoor, urban environments. The content and presentation of instructions for each of these situations is presented. A user study comparing a variety of interfaces (namely, spoken, tone outputs, compass or haptic inputs) [10] showed that the superiority of spoken directions (in combination with the compass) for a navigation task in an obstacle-free outdoor campus area. The latter study motivated us to explore a spoken interface for input and output. For the current study, described in more detail in Section 5.4, we have implemented only spoken interface output.

For more information on current technology for the blind we refer the reader to [11].

Chapter 4

Preliminary user study and problem statement

4.1 Interviews and ethnographic study

Realizing that the goal of our project is to design a system that can serve the needs of the user, rather than just to explore an innovative use of technology, and with the encouragement of Illah Nourbakhsh, who advised us during the early stages when the project was a part of his Principles of Human-Robot Interaction course, we conducted a number of interviews and ethnographic studies at Blind and Vision Rehabilitation Services of Pittsburgh [12]. The series of the interviews that we conducted with orientation and mobility instructors and an access technology coordinator helped us discover a number of facts that critically influenced the direction of our project and our final design. We also observed an orientation and mobility instructor conducting a typical training session on indoors navigation in a hallway and noted the use of verbal commands and the cane. Among the findings are the following:

- About 90% of the blind cannot travel independently; 7% use a white cane; 3% could use a guide dog but only about half of them choose to use a guide dog due to the burden of the caring for it.
- Regardless of the tool used, the factor that most determines a person's mobility is the use of essential personal skills.
- The ability to determine one's current location is one of the most important, yet challenging, skills to acquire
- It is as hard to get around inside as as it is to get around outside (airport, hotel).
- Knowing a big picture is important (knowing where I am before getting there).
- There is a psychological barrier and a stigma associated with using assistive devices, even canes.

- Speech is probably the best mode of interaction, despite the fact that it increases the load on the sense hearing, which the blind rely on for localization as well.
- The cell phone is the single most valuable piece of technology for the blind.

4.2 Design problem statement

Based on the preliminary user study and the review of the existing work, we have formulated the problem as follows: to design an indoor navigation aid that

- would assist in point-to-point navigation by giving verbal directions,
- would inform user about the current location,
- should not attempt to replace conventional mobility aids, such as a cane,
- should employ either audible, tactile or haptic interfaces,
- should ideally not occupy the user's free hand,
- should allow user to control the amount of chatter, or extra spoken detail provided by the system
- should not obstruct user's sense of hearing or draw undue attention.

At the same time, the desired system should try to overcome the challenges that were faced by the navigation assisting devices in the past:

- liability,
- cost,
- lack of landmarks,
- inconsistent use of Braille tags even in the buildings equipped with those,
- not all target users can read Braille.

In the following Section 5 we will describe our approach to solving this problem.

Chapter 5

Solution

The solution that we propose for this problem consists of an RFID reader carried by the user, and a network of inexpensive RFID tags in the building to be navigated. The RFID reader will be connected to a portable computing device such as a cellular phone. This device, the ETA, will use prepared map data to determine the user's present location and the route to a destination specified through a voice interface or using buttons on the device. This chapter discusses these components in greater detail.

5.1 ETA – Handheld device

The computing device to be carried by the user must be capable of interfacing with an RFID reader and provide multi-modal interfaces. In addition, it should be small, low–cost, and must not interfere with other navigation and orientation strategies used by visually impaired people. These requirements make cellular phones the ideal platform for the deployment of BlindAid. Several models of cellular phones targeted at blind users already include extensive speech recognition and generation technology. In fact, some phones are already being sold with integrated RFID readers. The use of such an ubiquitous general-purpose device is a clear advantage over an additional device that people must carry and learn to use.

For our prototype development, we decided to use a handheld computer – the Dell Axim X51v. It runs Windows Mobile 5.0 and is equipped with Bluetooth and software for synchronizing with a desktop computer. We chose to use this over a smart phone with the same software for ease of development with a larger screen and other useful features such as SD card slot and built in WiFi. However, the software we developed should run on other platforms, including cell phones, running Windows Mobile and have Bluetooth.

Figure 5.1: Dell Axim X51v used in prototype design

5.2 RFID

RFID is a relatively mature technology that has received much attention in recent years due to current and planned deployments. RFID tags are being used in varied applications from product inventory for retail stores to the new U.S. passport. With increasing use the price continues to decrease.

Depending on the frequency the tags use, the design of the tag antenna, the size of the reader antenna, and power levels RFID tags may have a read range of several millimeters to tens of meters. Our ideal design would have a range of around 1 meter. This would allow a tag on a doorway to be read when passing by it in the hall. Our ideal design would also use passive tags since they are cheaper to buy in bulk quantities. Our tags would form an infrastructure for user localization. Tags may be placed throughout a building with enough overlap to make localization possible at all times, with particular emphasis on building features such as doorways, elevators, intersections, or more specific to the locale, receptionist, customer services. As the user moves through the building, the system's knowledge of position and direction of travel can be determined based on the set of tags detected.

Given our desired range of 1 meter, we chose to use passive High Frequency (HF) tags which operate at 13.56 MHz and a range of up to 1 meter depending on the antenna designs. Ultra High Frequency (915 MHz) was also a possibility since it has ranges larger than 1 meter. But it is also more sensitive to metallic interference (i.e. when placed near metal wall beams), larger in size and is more costly [13].

Figure 5.2: Image of IDBlue RFID Reader.

5.2.1 RFID Reader – IDBlue

For the reader, we had to find one that reads HF RFID tags, is small and portable, and can also communicate with our handheld device. The reader we chose to use for our prototype experiments is the IDBlue, which is convenient in that it meets our desired requirements and because it could communicate through Bluetooth. This made communication with our handheld device wireless and allowed us to mount the device wherever we wanted to. It could easily communicate with both a PC and Pocket PC, and even had the form factor of a stylus (Figure 5.2). Further technical specifications can be found at the Cathexis website [14].

5.2.2 RFID Tags

For our prototype experiment, the RFID infrastructure consisted of partially labeling floors three and four of Newell-Simon Hall. Tags were placed at every doorway, intersection and corner of the areas as can be seen denoted by alphanumeric characters labeled in the floorplan (Figure 5.3(a) and 5.3(b)).

Tags were placed consistently to make it easier for the blind users to find. At each doorway, the tags were placed directly under a door plaque, located on one side of the doorframe. At each intersection and corner, the tags were placed on each wall (2 walls for every corner) at the same height as those placed under the door plaques. This common height placement made it easier for users to locate the corner and intersection tags. Another method to assist them was a recommendation to use the height of their canes relative to the tags as a frame of reference.

5.3 Map Data and Path Planning

In order to determine routes through a building to particular destinations, the ETA must be provided with the floorplan of a building, including the placement of all RFID tags. We envision

(a) Newell Simon Hall 3rd floor. Two experiment routes indicated by start (s) and goal (g) points and dashed or dotted lines.

(b) Newell Simon Hall 4th floor. Two experiment routes indicated by start (s) and goal (g) points and dashed or dotted lines.

Figure 5.3: Newell Simon Hall tag locations and experimental routes.

that this information may be downloaded to the ETA at the user's request, or when the presence of BlindAid RFID tags is detected at the entrance of the building. Alternately, map data may be built into special–purpose devices. This latter method can be used for other applications such as electronic tour guides, similar to the ones currently used in some museums. Since this map data is obviously specific to each building in which the system is used, map data must be generated for each RFID equipped building when the infrastructure is first embedded. The prototype design implemented preloaded maps for several floors of Carnegie Mellon buildings, including Newell Simon Hall as well as Wean Hall.

Path planning is implemented using Dijkstra's shortest path algorithm [15] over a graph structure. The vertices of the graph are the locations of interest for path planning: doorways, intersections, and corners. The edges of the graph are simply the hallways connecting them. Each vertex may have an arbitrary number of RFID tags associated with it. For instance, at least one tag is needed at every corner of a four-way intersection. In addition, the graph data files store the (x,y) image coordinates of each vertex to facilitate plotting a planned route in the graphical user interface. Given a scale for the image, this also allows us to compute the real-world distance between locations on the graph.

Once a path has been generated through the graph structure, this path must be translated into directions suitable for a person to follow. The vertex coordinates allow the system to determine

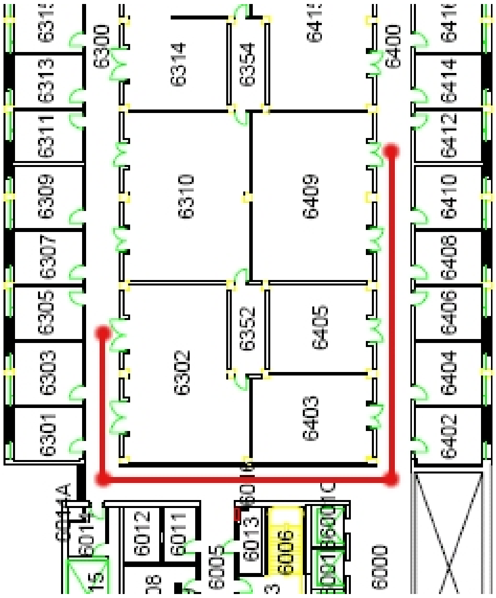


Figure 5.4: Example of directions given for navigation from room 6302 to 6409 in Wean Hall.

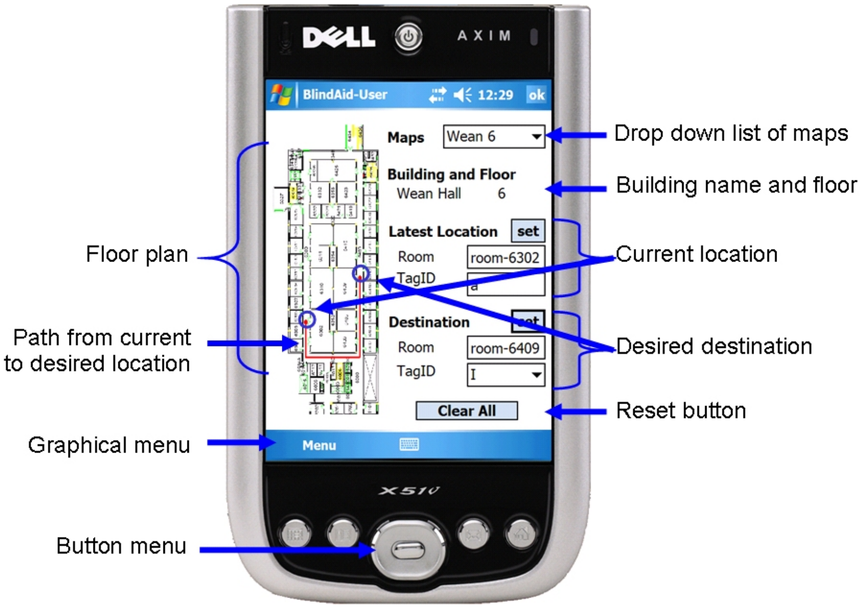
when a sequence of vertices are positioned in a straight line in a single hallway. When the direction of travel changes, the system finds the intersection where the change occurred, and determines the suitable landmarks necessary to instruct the user where to turn. The format of the generated directions is described in more detail in the next section.

5.4 Localization and Directions

The conceptual design incorporated speech recognition to determine setting destination. For our prototype studies, we decided to manually set the destination from a list of rooms, intersections and corners to decrease confusion and potential errors from untrained speech recognition software. When a destination is set, it is announced to the user. For the example going from room 6302 to room 6409 (Figure 5.4), the user would hear: “Heading to Room 6409.”

When a user localizes him or herself, the location scanned is announced to the user. For example when the user first localizes in front of 6403, “Room 6403” will be announced. The orientation of the user when scanning a tag is assumed to be facing the door or other object associated with the tag, or in the orientation of path following if the user is currently following directions from the system. The direction that the user should turn to travel the next step is also announced after the location. In the example, the device would advise: ‘Turn right.’

Given both a destination and a current scanned location, a path is automatically generated between them using Dijkstra’s algorithm as described earlier. The path generated by the planning algorithm is broken down into steps, where each step is a leg of the trip down one hallway.



BlindAid-User

Maps: Wean 6

Building and Floor: Wean Hall 6

Latest Location

Room: room-6302

TagID: a

Destination

Room: room-6409

TagID: I

Figure 5.5: Screen capture of first iteration GUI

For example going from room 6302 to room 6409 would consist of 4 steps :

- "Step 1. Walk to the 1st corner. Turn left."
- "Step 2. Walk to the 2nd intersection. Turn left."
- "Step 3. Walk to the 4th doorway on your left."
- "Step 4. You have arrived at your destination."

For the steps that involve just traversing down the corridor and turning into another one, only high level directions are given. When the user reaches the final hallway where the room is located, directions are specified in finer detail of how far to go based on the number of doorways they must pass on their left or right side. Blind users are usually trained to trail the walls on either side and their canes allow them feel for doorways, which makes this method of direction understandable.

In evaluating our prototype with the first four users, it was suggested that the step number be announced before each step to reduce confusion, particularly in the case of two subsequent steps having the same set of directions. This change is incorporated in the latest version of BlindAid.

5.5 Graphical User Interface

Figure 5.5 shows a screen shot of the graphical user interface that we used for conducting our experiment. We have a drop down list of available maps on the top right which allows us to switch between different buildings and floors. The updated building and floor is reflected in the labels on the right as well as the floor plan on the left. The two lower right regions specify current location and desired destination. Whenever the RFID reader scans a tag, it sends the RFID tag number back to the device. Our software then finds this tag in our database and determines the current position which then displays the room and tag information in the textboxes and draws the location on the floorplan map. As mentioned before, this location and orientation for the next step (if available) is also announced. For conducting experiments, we can also manually set the current location using the textbox and set button. In future iterations of the software, this set button may be removed and location will be determined using only RFID tag info. The destination boxes are similar. We manually set a destination for our users which updated the room number and tag id fields, as well as the location on the floorplan. The destination is also announced preceded by "Heading to ...". If there is both a current location and a desired destination set, our device automatically generates a path between them and updates it on the floorplan. There are two menus, a graphical one for sighted users, and one based on button controls. The next section will detail the menu further. There is also a reset button which clears the current location, destination and path.

With the second iteration of the GUI, additional features were included such as zooming in on the floorplan and recentering that map.

5.6 Menu

The menu allows the users to listen to the given directions. It can be accessed through the GUI or the hardware directional keypad located at the bottom of the device which has up, down, left, right and center buttons. The GUI has a few additional options which were not incorporated into the button menu to simplify usage for the blind user experiments. However, these additional options such as Connect/Disconnect, New Log and a more intricate hierarchical menu is envisioned for the final design.

Focusing on the button menu, there is an option to remind users of their destination using the center button (labeled by D in Figure 5.6(a)) which reannounces "Heading to ...". There is an option to list all the steps for the direction using the up button (labeled by A), and another option to hear only the next or current step using the down button (labeled by C).

The user can also chose to look ahead as far as they want by stepping through the directions using the left or right buttons for Next or Previous step respectively (labeled as N or P in Figure 5.6(b)).

(a) Button menu for Destination, All Directions, and Current Step.

(b) Button menu for Next and Previous Step.

Figure 5.6: Button menu for users to hear directions.

Chapter 6

Evaluation

In order to evaluate the effectiveness and usability of the BlindAid ETA, human trials were conducted with volunteers recruited from the Blind and Vision Rehabilitative Services of Pittsburgh. Participants were asked to locate a series of rooms in an unfamiliar building with and without the ETA. We measured the time required to find the destination as well as the number of times along the way that the participants paused to *relocalize*, or check their current location. Although the limited run of 4 participants did not produce statistically significant results, quantitative analysis is encouraging and we expect to conduct more experiments to confirm the usefulness of this device. Moreover, participants were generally enthusiastic and positive about the ETA. Given more time to get used to it, most of them expected their performance to improve even more. In addition, their comments and our own observations during the experiments suggested several improvements to the user interface and spoken directions. These suggestions, discussed further in section 6.3, will be implemented before further trials are conducted.

6.1 Experimental Protocol

The purpose of the experiment was to determine whether the use of the BlindAid ETA reduced the amount of time required for the user to reach a specified room in an unfamiliar building compared to the control situation of no travel aid. Of course, the effectiveness and efficiency of the user interface is confounded with that of the directions themselves. We used a questionnaire and interview to help distinguish between these areas and identify specific problems.

All of the participants in our study were experienced white cane users and could read Braille. They were all used to traveling independently, and one member of our team met them at the bus stop closest to the experiment venue. Upon their arrival, we executed the informed consent form before explaining the details of the experiment procedure.

Experiment participants were given the task of finding a specified room, given the room number. In the *control* condition, participants were asked to find the room as they normally might when faced with this task in an unknown location. Specifically, they used the braille plaques next to doorways to determine their current location, and their memory of recent room numbers to determine whether the room numbers were increasing or decreasing in their direction of travel. At intersections, they simply had to guess which way to turn.

In the *system* condition, in which participants used the BlindAid ETA, they were asked to follow the directions generated by the ETA as described in section 5.4. The destination was entered into the ETA by the experimenters, and the participants scanned RFID tags to allow the system to determine their current location. Each time a tag was scanned, the system would update its route and directions to the goal. Tags were placed immediately below the braille door plaques and on the wall at corners. Participants were instructed not to use the braille in the *system* condition.

The experiment used a 2×2 design. The *control* and *system* conditions were balanced to account for order effects, and participants were taken to another floor of the building between conditions to account for practice effects. Each condition consisted of two *runs*. That is, the participant was asked to locate two different rooms in each case, so we collected four data sets for each participant. Our primary quantitative measures were time (in seconds) to locate the room, and the number of times the participants localized themselves during a run. In the *control* condition, this is the number of times they read braille plaques. In the *system* condition, this is the number of times they scanned an RFID tag.

We conducted a short training session using the PDA immediately before the participant completed the *system* condition. This consisted of instruction and practice in the use of the user interface as well as the opportunity to follow a set of directions generated by the ETA.

After completing both conditions, we conducted an interview with the participant. We asked 25 questions that were answered on a numerical scale, and allowed an opportunity for open-ended feedback. We recorded audio during the interview. Participants were compensated $10 for their participation.

6.2 Quantitative Results

While the numerical results of the study appear promising, the differences between the *control* and *system* conditions are not statistically significant. The results seem to indicate an improvement due to the use of the BlindAid system, and we hope that the use of more participants in future studies will result in statistical significance of results. In addition, the implementation of some of the suggestions from users should increase the margin between the two conditions.

Figure 6.1 shows that the average time for a single run decreased by about 45 seconds (or 15%) when using the ETA. However, the large variance between subjects makes it difficult to draw conclusions. The plot in figure 6.2 shows a greater distinction between the conditions. On average, users stopped to localize about 2.5 fewer times per run with the system than without it, a 35% decrease. This indicates that people using the system may be more confident that they are heading

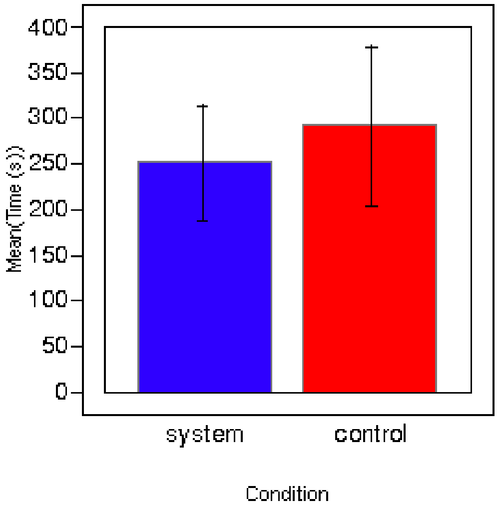


Figure 6.1: Mean time to complete a run.

in the right direction, or they at least trust the system to lead them in the right direction without double-checking its advice. Clearly, there is a correlation between these two measures, and any improvements in the generation of directions which can reduce the number of localizations should also decrease travel time.

6.3 Qualitative Results

Overall feedback regarding the ETA was overwhelmingly positive. All participants indicated that they would enjoy owning a device similar to the BlindAid system, and that their performance would improve with more time to practice using the system. Some specific comments indicated that the system successfully decreased the cognitive load that must be devoted to navigation so that the user could concentrate more on conversation. Another user remarked that people with get lost with or without the system; the only difference is that without the system, one can only find one's way again by luck.

Participants also offered some concrete suggestions for improving the directions produced by the ETA. One suggestion, already indicated in section 5.4 was to add step numbers to the list of directions. This helps assure a user that two subsequent identical directions (e.g. two consecutive right turns) are actually separate directions and not a glitch causing a single step to be repeated.

Users also suggested that the system distinguish between three-way and four-way intersections, and specify whether the user should trail the left or right side of a hallway. These distinctions are important to blind users who determine hallway features primarily by the use of their white canes. If users are trailing the right side of a hallway and pass through a three-way intersection that allows

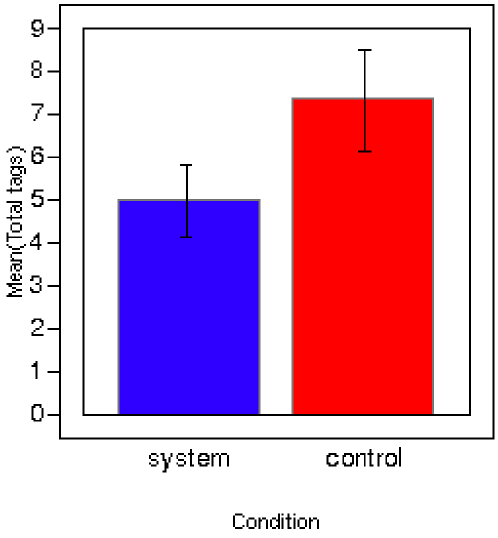


Figure 6.2: Mean number of localizations per run.

them to continue straight ahead or turn left, they may not realize that they have passed through an intersection. This can present a difficulty if they are trying to count the number of intersections they pass before making a turn.

Finally, users were also initially confused by the system's assumptions about the direction they were facing in a hallway. When the users got lost and strayed off the planned path, the system would attempt to guide them back in the direction from which they came. When they scanned an RFID tag which was not on the planned route, the first instruction was "turn around". While this instruction may be correct for a person walking down the hallway, the user must be stopped in front of a wall in order to actually scan a tag and produce this instruction. That is, the user would be facing a wall, and turning around would result in the user facing the other wall of a hallway. Once we informed the users of to the device's assumption, they immediately understood the "turn around" instruction. While thorough instructions can help align the users' models with that of the device, intuitive operation that requires no explanation would be preferable. Consequently, we have altered the system to presume that users face doorways when scanning tags, and the system tells them to turn left or right in order to proceed down the hallway.

6.4 Budget of Prototype

The total cost for our prototype experiments came to approximately $1127. The prices of items purchased are listed below and descriptions are given in Appendix A.2. Other possible products we considered purchasing are given in Appendix A.1.

Only the RFID tags would need to be purchased at each location intending to implement the BlindAid system. The rest of the cost would be incurred by users of the system, though the price should be significantly reduced by implementing the software on already-owned, general purpose devices.

$Price	Items
343	Dell Axim X51v 624 MHz
480	IDBlue RFID reader with Bluetooth
240	13.56MHz RFID tags (roll of 400)
30	RFID tag kit (various)
24	Blind mobility cane
10	Misc (velcro, ties, tape etc)
free	CMU floor plans
$1127	TOTAL COST

Note: Prices are rounded to the nearest dollar

6.5 Cost Estimate for Implementation

We required around 150 tags to equip most of the rooms located in Newell Simon Hall 3rd floor (which consisted of over 40 offices), and we estimate that the total number of tags to for the entire floor to be around 200. At $0.60 a tag, a rough estimate on the cost to equip a floor of comparable size in any building around $120 dollars.

Despite our low volume purchase, the cost of the tags were still reasonable and the cost to equip an entire floor is likely much less the cost of the braille signs for that floor. We have met our goal of an affordable system to aid in indoor navigation.

Chapter 7

Conclusions

This project has resulted in the development of an effective, low-cost ETA for blind and low-vision users. The device and the RFID tags used to instrument the environment are unobtrusive and low cost. In addition, the navigation system is useful for sighted people as well, further alleviating the association of the device with a vision impairment, and providing greater incentives for stakeholders to invest in instrumenting buildings with this technology. For example, directions and location information can be useful to delivery workers and other building visitors, search and rescue teams, and even museum tours can be conducted using this technology. These varied uses increase the value of the system for those who might be willing to invest in implementing their buildings with RFID tags, and could help spur the adoption of the system.

The use of commodity hardware and software using industry standard protocols such as Bluetooth lowers the overall cost of the device and increases chance of adoption by otherwise disinterested third parties. This includes commercially available technology such as RFID tags and readers, as well as the software which can be readily deployed to cell phones and PDAs for everyday use.

For this project to be successful, the system must be a worthwhile investment for blind users in terms of cost of equipment and time invested in learning to use it. This, in turn, depends on the wide deployment of RFID tags for the system, or at least consistent deployment within a particular area, such as the CMU campus.

Chapter 8

Future Work

Several directions for future work are immediately obvious. In particular, before conducting another round of user studies, we plan to implement all suggestions given by research participants in the first round, as described in section 6.3.

In addition, we would like to implement some of the features originally planned in the conceptual design of the ETA. In particular, we would like to port the software from C# to Java. Currently, only the "smart phones" with more extensive computing power runs Windows Mobile, whereas Java runs on nearly every modern cell phone. Thus using Java would allow us to reach a wider audience. Cell phones are not only an inexpensive platform, but they are also a very common convenience (especially among the blind population) and largely homogeneous in terms of capabilities.

The next goal is hands-free operation of the BlindAid system. The cell phone's Bluetooth connection can be used for the RFID reader and a Bluetooth headset. The RFID reader may be embedded inside the handle of the cane. Finally, we plan to implement voice recognition using Sphinx [16] for interacting with the system. Together, these advancements should allow the user to interact with the ETA entirely through a Bluetooth headset.

Acknowledgments

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Appendix A

Appendix

A.1 Appendix A: Product Research

Dell Axim X51 Dell Axims are handheld computers or Pocket PCs. Their latest is the Axim X51 in 3 versions: 416MHz, 520 MHz and 624 MHz for $224, $399 and $374 from Dell respectively. They all have Bluetooth and 802.11 wireless, CF type II and SD card slots and a head set jack for headset to support VoIP and voice recognition applications.

Bluetooth headset About $30. For demo when we want to imitate the real thing where a blind user would want to keep his hands free. Not mandatory.

Baracoda IDBlue, Bluetooth RFID reader Bluetooth RFID scanner would be a good and easy testbed for prototyping the communications aspect. The Baracoda IDBlue, is very small and light weight and pen sized. On Froogle, it costs anywhere from $500 to $600.

io RFID reader This ultra small reader can potentially fit it into a cane tip. io from Innovision R&T is the world's smallest and lowest cost RFID reader module. Measuring less than a US dime, io offers ISO14443A compatible 13.56MHz read/write functionality and is ideal for Near Field Communication (NFC) type applications. We are in the process of getting a quote.

13.56MHz RFID tags Frequency will work for both readers above. Costs anywhere from $0.60 to $1+ per tag.

Blind mobility cane Blind canes cost about $30

CMU floor plans We can apparently download the floor plans of all CMU buildings here `https://www.as.cmu.edu/~fsg/fl\_plans/index.html` for free. This would likely be helpful for our mapping stuff.

PocketSphinx speech recognition PocketSphinx is a version of the open-source Sphinx-II speech recognition system which runs on handheld and embedded devices. It currently supports embedded Linux and Windows CE (using the GNU arm-wince-pe cross-toolchain).

SOTI Pocket Controller software Connects from PC to PDA to view and control your Pocket PC/Smartphone from your desktop, using your desktop screen, keyboard and mouse. Connections can also be made via Bluetooth, allowing wireless communication between devices. License costs $34.95.

A.2 Appendix B: Products Purchased

Dell Axim Dell Axim X51v PDA 624 MHz Processor, 256MB ROM / 64MB SDRAM, 3.7 inches 480*640 VGA TFT Color LCD, BlueTooth / WiFi 802.11b/Infrared. From `http://www.amazon.com` for $343.49.

IDBlue RFID Scanner Baracoda/Cathexis IDBlue RFID scanner, 13.56MHZ. From `http://www.thenerds.net` for $480.48.

RFID tags sampler A Sample Pack of RFID HF Transponders. From `http://www.rfidusa.com` for $30.

Blind cane 56" W.C.I.B. Folding Cane. From Society of the Blind for $23.95.

RFID tags 13.56 MHz (HF) ICODE Passive Tags. From `http://www.gaorfid.com` for $0.60 each tag and 400 tags for $240.

Misc Velcro straps, twist ties, tape from Home Depot. Around $10 to $20.