Where's My Stuff? Design and Evaluation of a Mobile System for Locating Lost Items for the Visually Impaired

Julie A. Kientz[1], Shwetak N. Patel[1], Arwa Z. Tyebkhan[1], Brian Gane[2], Jennifer Wiley[1], Gregory D. Abowd[1]

College of Computing & GVU Center[1], School of Psychology & GVU Center[2]

Georgia Institute of Technology
Atlanta, Georgia, USA
+1-404-385-0257

{julie, shwetak, jwiley, abowd}@cc.gatech.edu, {arwa, bgane}@gatech.edu

ABSTRACT
Finding lost items is a common problem for the visually impaired and is something that computing technology can help alleviate. In this paper, we present the design and evaluation of a mobile solution, called FETCH, for allowing the visually impaired to track and locate objects they lose frequently but for which they do not have a specific strategy for tracking. FETCH uses devices the user already owns, such as their cell phone or laptop, to locate objects around their house. Results from a focus group with visually impaired users informed the design of the system. We then studied the usability of a laptop solution in a laboratory study and studied the usability and usefulness of the system through a one-month deployment and diary study. These studies demonstrate that FETCH is usable and useful, but there is still room for improvement.

Categories and Subject Descriptors
H.5.2 [**User Interfaces**]: *User-centered design*, *Prototyping;*
K.4.2 [**Social Issues**]: *Assistive technologies for persons with disabilities*

General Terms
Design, Human Factors

Keywords
Assistive technology, visually impaired, item location, mobile technology, ubiquitous computing

1. INTRODUCTION
The visually impaired, out of necessity, tend to be very organized when it comes to keeping track of important objects such as wallets, keys, or medication. However, many mundane objects are not part of the same strict daily regimen and may not be as closely tracked. According to a focus group we conducted, these items may include bottles of cleaning products while they are cleaning their homes, a stapler while they are working in their office, or their coffee cup in the morning. Although losing these items may not have the same sense of urgency as losing a set of one's keys, it can still be time-consuming and frustrating to find. Existing commercial item-tracking systems based on sounds (*e.g.*, the Sonic Keyfinder [15]) are prone to false positives and often require the help of a sighted person to use them. Additionally, these solutions are not very mobile, requiring separate installations or separate systems for all places where the user may lose an object. These individual solutions often unnecessarily add to the growing number of assistive devices that the visually impaired already carry around.

Through an iterative process, we have designed a mobile solution for aiding the visually impaired in quickly and easily tracking and locating objects. The system, called FETCH (**F**inding **E**verything using **T**echnology **C**onvenient and **H**andy), is completely mobile and uses Bluetooth-enabled tags similar to key fobs and a Bluetooth-enabled cell phone or laptop with screen readers (see Figure 1). The tags emit an audible beep and work within a range of 30 meters, a range large enough to find an object anywhere within a house, apartment, or office. Four users with visual impairments participated in a laboratory study, and four separate visually impaired users then used the system in their daily routine for one month to determine its usefulness for finding lost objects.

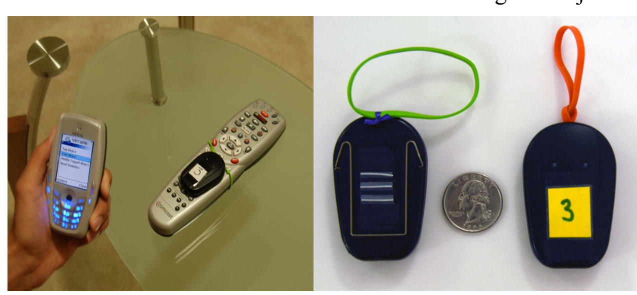

Figure 1: Left: User locating television remote control with phone. Right: Front and back of tags with a U.S. quarter to show size

In this paper, we discuss related work in item locator systems and item organization for the visually impaired and provide details on the design and implementation of the FETCH system. We then discuss the evaluation of the system and results, provide implications we uncovered for the design of these types of systems, and then conclude and discuss future work.

2. RELATED WORK

This work spans two key areas of research. The first of these areas is other uses of technology to locate lost objects for any population. The second area is in technology to aid the visually impaired interact with the physical world, such as through navigating it or identifying objects within it. Below we explain how our work fits into and builds upon previous research in these areas.

2.1 Finding and Tracking Lost Objects

Systems for addressing the problem of finding lost objects have been investigated widely both commercially [3, 4, 5, 10] and in research [12]. The most similar system to ours is a commercial product called The Locator [6] from the Gloucestor Smart House. This system uses an audio paging system for locating objects tagged around an environment. The Locator uses a proprietary radio frequency and requires custom devices, whereas our system uses the more standardized Bluetooth communication protocol and thus will work with existing Bluetooth enabled devices. It is also not designed to be accessible for individuals with visual impairments, has a much shorter range than our Bluetooth solution, and is a bit more expensive than our solution. The main advantage of our system over existing commercial ones is that it is mobile: items can be tracked outside the home. Other solutions exist that are activated by either clapping or whistling [15]. Although this solution does not require an additional paging system, it is sometimes prone to false positives and does not allow unique identification.

Another method for finding objects in the home is through the use of computer vision and computational perception [8]. This system uses cameras to track when objects of interest are moved within a space and can thus report the current location of any object within its field of view. This system is not currently cost effective compared to other solutions, but has the benefit of being able to passively track objects. Ma and Paradiso [7] present a solution that uses a flashlight to activate tags on objects around an environment, causing an LED on the tag to glow. While technologically novel, the current version is not well suited for users with visual impairments.

Other researchers have also explored finding lost objects for the general population. Peters *et al.* [12] surveyed many users on the types of objects that are commonly lost and also included an overview of various strategies used in finding objects. They developed a set of guidelines for use in developing solutions a system to help find lost objects. Inspired by their work, we sought to uncover which items individuals with visual impairments often lose, their strategies for finding or preventing loss, and guidelines for developing a technological solution.

2.2 Helping the visually impaired interact with the physical world

Several research projects recently have focused on assisting the visually impaired navigate and locate obstacles and objects in new environments. For example, researchers have used audio clues, both using spoken words [13] and sonification [2, 11, 16], to help the visually impaired navigate new spaces. Our system uses a similar technological solution for locating and communicating with other devices in the environment, but differs in that the primary application is finding objects that a user may have misplaced, rather than helping the user navigate or learn a new environment.

Several research and commercial systems exist in aiding the visually impaired in identifying groups of similar objects. For example, the Scan-A-Can system will scan anything with a barcode, such as cans of food or compact discs, and read aloud the product name and contents [14]. Although this system is useful for identifying objects, the current cost of this system is prohibitive to large-scale adoption and assumes the user knows the location of the item. Our system differs from the Scan-A-Can system because it is a low cost, mobile solution designed to locate lost objects, rather than identifying objects at hand. Similar object identification systems, such as color identifiers [1] or money scanners [9], allow the visually impaired to identify objects amongst groups of similar objects, such as clothing or paper money and are very specialized in purpose. We designed our system to be versatile and be applied to any object, rather than have a specialized purpose, and to utilize something the individual is already likely to carry, rather than having them carry an extra device.

3. THE FETCH SYSTEM

3.1 The Design Process

The design of FETCH is a result of a participatory design process with individuals with visual impairments. We conducted an initial focus group with five visually impaired adults aged 40-65 (4 females and 1 male). The onset of blindness varied from individual to individual, ranging from blind since birth to legally blind for 5 years. Additionally, their degree of blindness varied in that some had full blindness and others had partial vision or could at least detect the direction of light and see shadows.

During the focus group, we asked our participants questions about their strategies for organizing objects and learning new spaces. Neither learning new spaces nor organizing things such as clothing, food, or CDs was a major problem reported by our participants. Most had a specific strategy for keeping track of important items, such as keys, wallets, or phones. One of their biggest frustrations, however, was to locate items used temporarily while moving about a space. Items cited in particular were cleaning products, coffee mugs, water bottles, and office supplies (*e.g.*, a stapler). Several participants cited being frustrated if lost their bottle of cleaning solution while in process of cleaning.

The participants also discussed current solutions for recovering lost objects. Many had previously used commercial tagging systems, but reported being "annoyed" by false positives and were turned off by the cost, complication, and inflexibility of other commercial tracking systems. We saw an opportunity to design a more useful and usable solution to help the visually impaired locate lost objects.

3.2 Overview of System Design

A primary goal of this work was to utilize devices an individual may already own and be comfortable with operating. This would allow us to offer the functionality of item location without having to carry an extra device, as visually impaired individuals already carry many different devices or navigation tools, such as a cane, a guide dog, a notetaker, or a personal music player. Thus, we chose a solution that uses Bluetooth enabled tags that another device, such as a cell phone, laptop, or PDA, can activate with Bluetooth technology. Use of these existing devices, rather than a custom solution, can eliminate the need for users to learn a new device and carry around another one for one highly specific purpose. The focus group participants voiced strong support for technological solutions that required a minimum amount of time and effort to learn. Additionally, use of devices with which people already interact regularly adds to system convenience.

The basic process for using the system on a mobile phone is as follows (see Figure 2). The user decides which object to track and chooses any tag not already associated with another object, or she may choose to overwrite an existing object assignment. She obtains the tag ID number by feeling how many ridges are on the object. She speaks aloud the name of the object, and the phone records it as a sound file (to avoid having to type in letters on a phone keypad). She then enters the number associated with the tag they have chosen, which she identified by feeling the ridges. When the user loses an object, she goes to her phone and chooses "find object." The system reads aloud all items currently tracked by the system, and she selects which one she wants to find. Once she selects the item, the system activates the beeping on the tag. After locating the object, she presses a key on the phone to stop the beep.

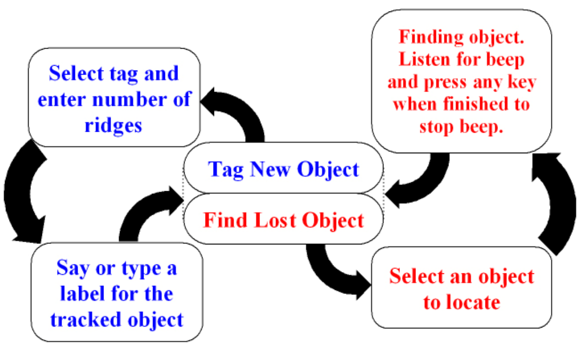

Figure 2: Overview of interaction flow of locator system

Our system consisted of two interfaces options: one on a laptop (Figure 3) and one on a mobile device (Figure 4). Both interfaces allowed users to assign labels to tags and to initiate the beeping and stop the beeping of the tags. The processes for registering objects and locating items is the same, but the main difference between the phone and laptop versions is that the user types in the label for the object, rather than recording a sound file. The interface included only text and was designed for use with all typical screen readers on both computers and mobile phones. Additionally, we used large fonts for those with partial vision. The tags themselves had different numbers of tactile ridges on the back of them, so users could feel them to identify to the system which tag they were assigning to which object. For users with partial vision, we also had large numerals on the tags to aid in reading. If the tag is not within Bluetooth range, it will keep prompting them to start the beeping unless they cancel. That way, users can walk around their space and keep pressing the "beep" button until they come within range of the tag.

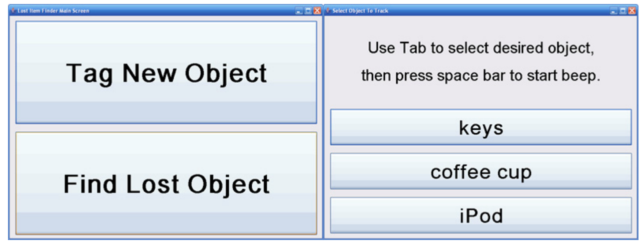

Figure 3: Sample screens from laptop object location interface. Left shows main menu, right shows list of objects.

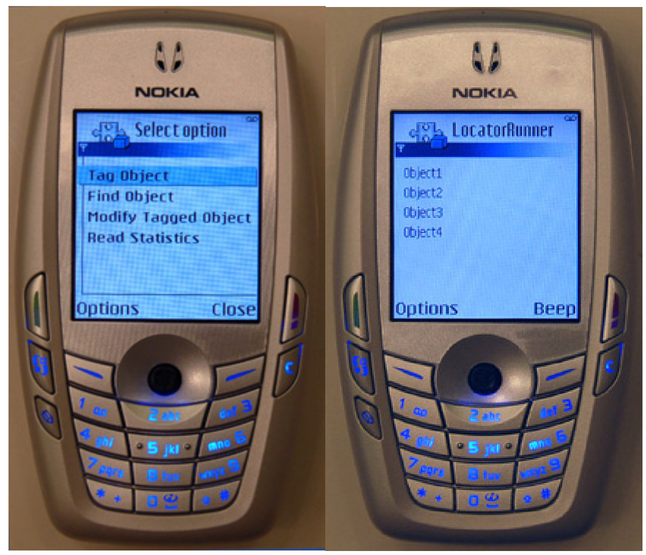

Figure 4: Sample screens from mobile phone object location interface. Left shows main menu, right shows list of objects

3.3 Implementation of Item Locator System

We used custom-built Bluetooth tags manufactured by Bluelon, Inc. as the technology to implement the tracking system. The tags include a low-power CSR BlueCore-02 Class 2 Bluetooth RF module with an integrated antenna and a 3.7 V 345 mAh lithium ion battery. They require charging approximately every 2-3 weeks, and a 2.6 kHz speaker on the tag beeps when the battery is low or is activated by a Bluetooth device. The number of ridges on the tags, used for identification, corresponds to its Bluetooth MAC address, which the application uses to toggle the appropriate tag.

The mobile version of FETCH is written in Java 2, Micro Edition (J2ME) using the MIDP 2.0 and JSR-82 Bluetooth specification. The application was designed for the Nokia Series 60 platform, but can be used on any phone that is equipped with J2ME and has Bluetooth capabilities. We use the Mobile Media API (MMAPI) of J2ME to record voice input from the user and play the object names when the user wishes to locate an object. In order to store application data permanently, we use the MIDP Record Management System (RMS). We store data such as the recorded object name, the tag number associated with the object, and the number of times the particular object has been searched. Lastly, we use JSR-82, the Java Bluetooth API, to instruct the tags to beep when the user wishes to locate the object, and to stop beeping once the user has completed their search.

To increase accessibility of the phones and our software, we installed the Nuance Accessibility Suite, specifically built for Nokia Series 60 phones. This suite consists of two software modules: TALKS, a screen reader that reads out all the text on the screen, and ZOOMS, a screen magnifier. The suite uses the ETI Eloquence text-to-speech software. The laptop version features a similar implementation to the mobile phone version. The application is written in Java and the Bluetooth radio is accessed through a serial connection. We used the JAWS screen reader application to read aloud the text of the interface for our prototype system.

4. LABORATORY STUDY

The purpose of our laboratory study was to get an initial feel for the usability of our tag tracking system design for the visually impaired and give it a "stress test." Our first development was on the laptop, and we evaluated our system design before attempting the more difficult development on the mobile phone.

4.1 Study Design

Four of the five visually impaired focus group participants evaluated the prototype system on the laptop. The evaluation sessions were conducted individually. Participants were given a set of tasks to complete: discriminate between tags with different IDs, assign an object name to a tag with a specific ID, attach the physical tag to an object (a stapler or a cleaning product canister), activate the tag (start the beeping), and stop the beeping.

We collected task completion rates for each task. Following each task, participants were asked three questions: "Is this method effective?", "Do you have suggestions for improvement?", and "On a scale of 1-10 with 1 being very difficult and 10 being very easy, how would you rate this task?". After completing the four tasks with each object, participants answered questions about the overall ease of use of the system. Additionally, participants answered questions about potential design alternatives, including using audio (verbal labels or distinct tones) to identify tags.

4.2 Results

Overall, the prototype system successfully allowed participants to attach multiple tracking tags to objects, use the software to register tags, and use the software to activate these tags. All four participants successfully completed the tasks. All participants rated the ease of completing the tasks as "very easy" (*i.e.*, 9 or 10 on a 10 point scale). The biggest difficulty participants had was acquainting themselves with the layout of our laptop keyboard. Participants stated that they would find the system useful for tracking some of their objects, such as cleaning products, coffee cups, and office supplies. One participant suggested that the high pitch tone emitted by the tags might be too high for people with hearing loss, such as presbycusis. One potential solution, she said, would be to have a tone that modulates between a low and high pitch.

All participants stated that they would consider buying the system if it was priced at our estimated cost. We told them we expected the system to cost about $100, if the person already has a computer. This expected cost includes the cost of a Bluetooth dongle and four tracking tags.

One participant recommended that we design the system to be useful for people who do not have or do not want to use a computer. This participant wanted a separate, mobile base station that could activate the tag. Additionally, this participant stated that she would probably only use one tag at a time. This participant preferred a system with only one tag and a separate base to activate that tag. This minimal system would not require uniquely identifying tags, because there would only be one tag for the system.

Participants also gave feedback on the physical tags. All participants liked the ridges on the tags. Two participants commented that the ridges would be preferable to dots or Braille, because people with diabetic neuropathy might not be able to use smaller dots. In addition, participants felt that the size of the ridges and the distance they were raised from the surface (about the thickness of a paperclip wire) was appropriate. Three participants suggested that something sturdier than a rubber band (such as an elastic band with a thin cloth covering) would be better to attach tags to objects. Two participants mentioned that magnets could be used to attach the devices to metal objects. Several participants also requested that the tags be smaller, so that they could fit on smaller objects (*e.g.*, sunglasses). Finally, all participants said that they would prefer to have one size and shape for all the tags.

5. DEPLOYMENT WITH DIARY STUDY

After the participants in the laboratory study discussed the convenience of a mobile device capable of activating the tags, we developed the mobile phone version of FETCH. Since we had already determined the concept of the system design was easy to use, we wanted to see how our technology fared in real use.

5.1 Study Design

Although the laboratory study was useful in determining the usability on a laptop, it is also important to explore uses in everyday life. Deployment of the technology allowed us to determine its usefulness in terms of when and for what people might use the system. Additionally, we needed to determine the usefulness of having the phone on their mobile device. Finally, we aimed to determine whether the system was successful along the following criteria:

1. Increases success rate of finding lost objects
2. Decreases amount of time it took to find a lost object
3. Decreases frustration level associated with finding objects

We conducted a 2-phase deployment study with four users with visual impairments (one of these individuals had also participated in the focus group and laboratory study). The participants varied age, background, their level of impairment, and their living situation (*e.g.,* whether they lived alone or with family or roommates) (Table 1). The two phases of the study involved having users keep diary entries on lost items without and then with FETCH.

The purpose of the diary study was to understand how often our participants lost objects, what items they lost, how long it took to find objects, and the level of frustration associated with finding objects. In the first phase of the diary study, FETCH was not used. This gave us a baseline measure of how often participants lost objects and if they successfully found them. The purpose of the second phase was to see if our item locator technology would improve the user's experience according to the above criteria.

During both phases, participants recorded a diary entry each time they lost an object. We gave the participants the option of using a custom-made application on the phone that would record their entries, calling a phone number and leave a voice mail, or keeping a diary on their computer and sending it over email.

Table 1: Participants in deployment with diary study and qualitative analysis. The last column indicates whether the user had FETCH on their primary phone or a separate device.

User[1]	M/F	Age	Impairment	Living situation	On Phone?
Pam	F	55	Full	With family	No
Mia	F	23	Partial	Alone	No
Kim	F	40	Partial	With spouse	Yes
Tom	M	22	Full	With fiancée	No

In both phases of the diary study, participants answered four questions each time they lost an object, regardless of whether or not they found the object or if it was something for which they used FETCH. The questions were as follows:

1. Which item did you lose?
2. Did you find it?
3. If yes, how long did it take to find? If no, how long did you look for it?
4. On a scale from 1 to 7 (7 being highest), please rate your level of frustration associated with losing this object.

These questions focused on the potential need for the system, based on the number of items lost in the four-week period, and the success metrics outlined above.

The entire study lasted approximately one month - two weeks each for the first and second phases. The first phase of the study allowed us to provide the users with the new mobile phone so that they had time to learn how to use it and use it to record their diary entries if they chose. Due to a limited base of users to deploy with, none of our participants currently had a mobile phone that was capable of running both the application and had Bluetooth, though they all currently used a mobile phone. We had the additional constraint that the Nokia phones we had available only worked with GSM phone service, which only one of our participants had. We swapped SIM cards for that one participant, and she used it as her everyday mobile phone. The other three participants had to use our augmented mobile phone as a secondary device. Though this was a disadvantage for our deployment, we believe the proliferation of Bluetooth on mobile phones will result in more participants having this capability in the future.

5.2 Results

The results of our diary study showed many differences in how our participants used the system and the rate at which they lose objects. In the first phase, we found that participants lost anywhere from one to five items each in a two week period. There was a wide variety of items lost; however, the frustration level associated with losing each item was generally high, with an average of 4.75 across all participants. Additionally, while some objects were found right away, others took several days to find and the participant had to ask someone to help find it or wait for them to stumble upon it later (Table 2).

Table 2: Objects lost by participants in Phase 1. The last column (FL) indicates the frustration level reported by participants on a scale from 1 to 7 (7 being most frustrated).

User	Object Lost	Found?	Time to Find	FL
Pam	Razor cover	Yes	2 min.	3
Pam	Sunglasses	Yes	5 min.	5
Pam	USB drive	Yes	10 min.	6
Pam	CD case	Yes	10 min.	6
Mia	Container lid	No	Several days	4
Kim	Comb	Yes	5 min.	3
Kim	TV remote (twice)	No	2 days	6
Kim	Keys	Yes	30 min.	5
Kim	House phone	Yes	5 min.	2
Tom	Cell phone	Yes	1 hour	7
Tom	Notetaker	Yes	30 min.	5
Tom	iPod	No	Several days	5
				Average : 4.75

In the second phase of our study, most participants reported losing more items than in the first phase, with the exception of Pam. Most of the objects lost were similar to the first phase, but the ones that used the object tracking system found the process to be much quicker and less frustrating. Although we did not specify they do this, users only kept diary entries for items they lost that were tracked with FETCH. Participants explained in their post deployment interviews that they thought they were only evaluating items lost by the system, so we do not have data on items that were lost in the second phase not tracked with FETCH.

Kim, who was using FETCH on her primary mobile phone, reported the most use of the system. She reported using it 2-3 times per day and found it very easy to track her water bottle and her television remote. She said she always knew where her phone was, so when something was lost she could locate the object quickly and easily. She also reported that she "lost" the item more

[1] We replaced the names of the participants to protect their anonymity.

because it was much easier to find, whereas in the first phase of the study, she did not consider something lost until she had spent at least 2-3 minutes looking for it. Also, she said she would often use FETCH to find the TV remote when she walked into the living room just so she would not have to think about where she last left it.

Table 3: Objects lost by participants in Phase 2. FL column indicates Frustration Level. If an item was listed as being lost multiple times, we averaged the time to find and FL.

User	Object Lost	Number Times	Found?	Time to Find	FL
Pam	Water bottle	1	Yes	3 min.	2
Mia	Keys	3	Yes	1 min.	1
Kim	Water cup	6	Yes	1 min.	1
Kim	TV remote	11	Yes	1 min.	1
Tom	Cordless phone	1	Yes	1 min.	1
Tom	Notetaker	3	Yes	1.3 min.	1
Tom	iPod	1	Yes	2 min.	1
					Average : 1.14

Contrary to our expectations, most users did not swap tags on objects as often as we expected them to. Two of our participants reported experimenting with placing them on different objects to see where it would be the most useful, but most did not have more than three objects they needed to track. Thus, they would put the tag on their most frequently lost item and leave it there unless needed for something else.

Overall, we saw an increase in the success rate for finding lost objects and a decrease in the time it took for users to find objects if they were tracked by our system, with most users finding their object within 1-3 minutes. Additionally, we saw a decrease in the frustration level associated with finding objects. This makes FETCH successful on the three levels we judged it on, however, the small number of samples in our study and the fact that not all lost items were recorded during Phase 2 should be taken into consideration.

6. QUALITATIVE EVALUATION

Our limited study time and small number of participants means that we may not be able to determine empirically how useful FETCH was for the visually impaired. Thus, we supplemented our deployment results with qualitative feedback obtained through interviews with our participants.

6.1 Study Design

After completing the diary study, we interviewed the participants on their actual and perceived use of FETCH. This was especially important to us, because we were unable to deploy under our ideal conditions (*i.e.*, all users using their own phones they were familiar with for more than four weeks). During this time, we asked them what improvements we could do to increase the usability and usefulness of the system. The interviews were open-ended, and we gave participants the option to criticize the system on its feasibility and usefulness. Each interview lasted about 30 minutes, and we conducted them immediately after the second phase ended. The main goal of the interviews was to understand what factors contributed to the use of the system and which did not. Additionally, we wanted users to speculate how use of the system would change if they were using their primary phone or laptop to track the objects.

6.2 Results

The results of the interviews showed that most participants found FETCH to be useful and can see having it as part of their daily routine on a regular basis. They all believed having the tracking system on their current phone would be much more convenient than having a separate "base station" device approach that many commercial systems use, because it is too big to carry around at all times.

> **Tom:** *"I already carry around a notetaker, an iPod, my cane, my laptop… Having to carry around a special device just to find things is just one more thing I have to carry and something else that can get lost."*

Though in our deployment all of our participants primarily used the tracking system in their home, they all mentioned tracking objects outside the home would be useful,, because they are often in locations in which they do not have complete control. For example, Mia mentioned how useful it would be to locate her luggage after she returned from a trip at the airport. Usually in this case, she would have to find a sighted person to help her locate it. Pam stated she would use it to find her coat on a rack at a restaurant, or to find her purse under a table.

> **Pam:** *"Losing stuff outside my home is more urgent, I think. If I lose something inside my home, I will eventually find it. Either I will stumble across it, or someone else will find it for me. But if I am out and I don't find something quickly it may be lost forever."*

One of the other participants, Tom, said he would like to leave a tag on his seat when taking a quick break at a conference or show, and then use his phone to find his original seat. He mentioned a concern about disturbing others with this tag, so he would have to experiment to see in which situations this was socially acceptable.

Several of our participants stated that they would like to use it for identifying which object is their's out of a group of several similar objects. One participant mentioned that she would attach the tag to her cane when together with several other visually impaired users, since all canes are very similar, and it is often difficult to tell them apart by touch alone.

Three of our participants liked the idea of having multiple options for devices they could use to locate their items. For example, they stated they would find it useful to be able to locate items using their mobile phone, a laptop, or a separate base station, so they could just go to whatever was nearest to find items more quickly. They stressed that being able to quickly tag and find items was very important. As evidenced by our one participant who used the tracker on her primary phone, we found that because the barrier was lower for her to use the system, she used it the most out of anyone. She was also the one participant who did not feel that multiple options were necessary and said she would like to have it just on her phone.

> **Kim:** *"It would be nice, but not necessary…it's [my phone] is always with me, and I always know where it is."*

Though we only gave each person three tags, we asked them after the deployment what they would use the system for if they had infinite tags at a small size. Across all our participants, they listed the following potential items they would track: hairbrush, cane, purse, luggage, backpack, coat, sewing bag, glasses, pen, and signature guide. One person said he would like to be able to track anything that moves continuously, which includes things such as his notetaker, phones, keys, television remote, and cane.

Lastly, we asked participants to discuss the features they liked about FETCH. All reported that once they were used to the screen reader on the phone, they found it very simple to use. They appreciated that it took advantage of devices they already owned, instead of requiring them to buy a separate device. One participant reported an appreciation of the Bluetooth tags working everywhere in her multiple story house, which is further than other commercial systems she had tried using in the past. Pam closed her interview by saying that she appreciates anything that allows her to be more independent and find things without the help of others.

7. DISCUSSION

Though our study only consisted of a few users, we believe that we found interesting results that can help inform designers of technology for the visually impaired. The types of objects lost and the number of times they were lost gave us a good idea of what kinds of item for which FETCH would be useful.

7.1 Improvements to the FETCH system

Through the laboratory study and the post deployment interviews, we determined several ways we may be able to improve upon our system. Though our focus group suggested they would need tags for temporary use, many of our participants stated they often did not anticipate losing the things they did. This leads us to conclude that a system with tags that are both permanently assigned to objects and tags that can be used temporarily. This means that tags should be small enough and cheap enough to tag many objects, and require little maintenance on the part of the user (*e.g.,* they should not have to be charged daily). Some of the objects were lost because other people they lived with moved them, not because they themselves thought they might lose it. For example, Mia, our one participant who lived alone, had the lowest rate of lost objects across both phases of the study.

All but one of our participants said the tags were useful for big things, but they would like to have smaller tags to attach to commonly lost small things, such as sunglasses or pens. However, Kim said she tended to only lose items big enough that the tags could accommodate.

> **Kim:** *"If something is that small, it's probably also something easily replaceable….like a pen or something. Though I suppose jewelry might be an exception."*

Another feature request was having different tones or beep frequencies for different tags, so visually impaired users in groups could use their separate systems at the same time (*e.g.,* identifying whose cane belongs to whom).

7.2 Design Considerations for Item Location and Identification Technology

Based on the analysis of our study results, we have identified several key considerations when developing item tracking technology for the visually impaired, as well as design considerations for mobile technologies in general.

The visually impaired do not always anticipate what they will lose

Our focus group participants told us that they would remember to tag objects before they lost them, but in practice, we determined this was not actually the case. There were several instances where people lost objects they did not anticipate losing, such as the lids for containers. This need of our participants calls for more research into developing small, cheap, and potentially disposable tags for tracking personal items around spaces. Because this technology may be far away yet, we can compromise by offering tags for permanent assignments, and smaller, temporary tags that do not require a registration process at all.

Solutions for tracking outside the home may be important

Though our users did not use FETCH outside their homes during our study, all of them mentioned hypothetical uses for it. We believe we may have seen more of these uses if we conducted a longer study where all users had been using it on their primary mobile phones. In her interview, Kim mentioned she was more likely to run into situations where she would need to temporarily assign a tag to an object outside her home. Thus, if she were using the system for longer she said would always keep a tag in her purse for impromptu occurrences.

Integration of assistive technologies into devices already being used can lowers barriers to use and increase utility.

We found the most use of FETCH by Kim, the person who had it installed on her main mobile phone. In her post-deployment interview, she said this was a major convenience, and she would even use it in situations where it might not have been completely necessary. We did not see this behavior in our other users, and many of them expressed a desire to have the device on their mobile phone. After the deployment, Tom said he liked having such a capable phone that he asked where he could purchase the Nokia 6620 and how to buy the screen reader. He said he hoped that other companies would develop more assistive technology for mobile phones, so he did not have to carry around as many devices.

7.3 Designing Mobile Applications for the Visually Impaired

Our primary goal for this study was to develop a solution that would meet the needs of our users for easily and conveniently locating missing items. However, since one of our solutions was to add the capability to a mobile phone, we uncovered several interesting accessibility problems in designing mobile phone applications for the visually impaired. For one, screen reader technology for mobile phones is limited to only a select set of expensive phone models, because of its computational requirements. This means that currently, designers cannot assume that individuals will have screen readers on their existing phones.

Additionally, we learned that the current J2ME programming environment is limited in how accessible you can design programs. For example, some of the widgets available on the phone, such as the text entry window, do not allow you to increase the font size for participants who are visually impaired, unlike on many GUI builders for desktops. Mobile phone screens are also inherently small, which means designing for low vision users may be difficult. However, this small screen size may not be an issue if a completely auditory interface can be developed. Text input for the visually impaired on mobile devices is also extremely difficult, which is why all of our user input (aside from entering a number for the ID of the tag) had the user voice record a sound file rather than typing in a label, as in our laptop version.

8. CONCLUSIONS AND FUTURE WORK

We have presented here an entire design process for developing a ubiquitous computing application for the visually impaired, from the initial formative stage to a full deployment and evaluation. Though there have been many attempts to develop similar tracking systems, we believe our system has an advantage over others by integrating the system into an existing device. The deployment and diary study showed that FETCH was useful in helping the visually impaired track and locate objects around their homes, and the qualitative analysis shows that there are many perceived uses for outside the home. Our participants strongly preferred to have a device on their mobile phone, as opposed to a separate system, and most liked the idea of using whatever was closest to find an item, such as having the option to choose between their mobile phone and laptop.

Though we feel our initial prototypes were successful, there is still room for improvement and future work on this type of tracking system. Several of our participants requested smaller tags, as well as a larger quantity of tags, which calls for research into making the Bluetooth tags smaller and cheaper. If we add additional tags, we will also need to redesign the interface to address scalability issues, as we designed FETCH to read aloud a short list of all items tracked. Additionally, there are ways we could make the system more flexible, such as using different tones for different tags to help with identification among tags. The process of identifying tags could also be simplified. For example, if we also equipped the tags with accelerometers, FETCH could just request that the user shake the tag she wishes to use instead of entering the number of ridges on a tag. Lastly, we can explore ways of developing our application without requiring a screen reader, which will increase the number of phones capable of running the system.

While we designed FETCH specifically for visually impaired users, we believe that it has uses beyond that population. Losing objects is such a common occurrence that many anyone can benefit from such a system, making FETCH an example of something universally designed.

9. ACKNOWLEDGMENTS

We would like to thank our participants and those who helped recruit from the Atlanta Center for the Visually Impaired. We thank Bruce Walker for his advice and feedback on planning and evaluating this type of application and Gillian Hayes for her helpful comments on the writing of this paper. This work was sponsored in part by the National Science Foundation and Intel Corporation. Additionally, Nokia Research, and in particular Dana Pavel, donated the phones used in the deployment and VisionCue supplied us with registration codes for the TALKS mobile phone screen reader. This work is covered under Institutional Review Board protocols H06130 and H05247.

10. REFERENCES

[1] Cobalt Systems Colour Detector. http://www.cobolt.co.uk/. 2006.

[2] Dellaert, Frank, and Tariq, Sarah. "A Multi-Camera Pose Tracker for Assisting the Visually Impaired." 1st IEEE Workshop on Computer Vision Applications for the Visually Impaired, 2005.

[3] Find One, Find All. http://www.findonefindall.com. 2006.

[4] FindIT. http://www.ambitiousideas.com/findlostkeys.htm. 2006.

[5] KeyRinger, http://www.keyringer.com. 2006.

[6] Locator, The. Gloucestor Smart House. Bath Institute of Biomedical Engineering. Available at http://www.bath.ac.uk/bime/projects/smart/index.htm.

[7] Ma, Hongshen, and Paradiso, J.A. "The FindIT Flashlight: Responsive Tagging Based on Optically Triggered Microprocessor Wakeup," in *Proc. of the UbiComp 2002*, Gotenborg, Sweden, October 2002, pp. 160-167.

[8] Nelson, Randal and Green, Isaac, "Tracking Objects Using Recognition", in *International Conference on Pattern Recognition (ICPR02)*, Quebec City, Quebec, August 2002, Volume 2, 1025-1039.

[9] Note Teller. http://www.brytech.com/noteteller/. 2006.

[10] Now you can find it! http://www.sharperimage.com. 2006.

[11] Oh, Sang Min, Tariq, Sarah, Walker, Bruce, and Dellaert, Frank. "Map-based priors for localization." Proceedings of Intelligent Robots and Systems, IROS 2004. 2004.

[12] Peters, R.E., R. Pak, G.D. Abowd, A.D. Fisk, W.A. Rogers. "Finding Lost Objects: Informing the Design of Ubiquitous Computing Services for the Home." Georgia Tech GVU Technical Report: GIT-GVU 04-01. 2004.

[13] Ross, D. A. and Lightman, A. 2005. Talking braille: a wireless ubiquitous computing network for orientation and wayfinding. In *Proc. SIGACCESS Conference on Computers and Accessibility*. Baltimore, MD, USA, October 09 - 12, 2005. Assets '05.

[14] Scan-a-can - http://www.maxiaids.com/store/prodView.asp?idstore=6&idproduct=662&category=Scan/Read_Devices&product=Scan-A-Can_for_Windows_Deluxe

[15] Sonic Key Finder. http://www.keyringer.com/sonic-key-finder.html. 2006.

[16] Walker, Bruce, and Lindsay, Jeff. "Auditory navigation performance is affected by waypoint capture radius." In Proc. of Auditory Display ICAD2004, Sydney. July 2004.