VTAssist – A location-based feedback notification system for the disabled

Sarav Bhatia[1], Curtis Dahn[2], Jason Chong Lee[2], Miten Sampat[2], D. Scott McCrickard[2]

Bradley Dept of Electrical and Computer Engineering[1]
Virginia Polytechnic Institute & State University
Blacksburg, VA 24061-0111
1-540-231-6646
saravb@vt.edu

Department of Computer Science and Center for HCI[2]
Virginia Polytechnic Institute & State University
Blacksburg, VA 24061-0106
1-540-231-7409
{cdahn, chonglee, msampat, mccricks} @vt.edu

ABSTRACT
The needs of individuals with limited mobility have not been given as much importance as those of other users of internet-accessible mobile devices. Disabled users have information and service needs that are unique and a timely delivery of these services and information can be invaluable. This has motivated us toward the development of VTAssist, an application that attempts to provide critical location-based information about building accessibility to impaired users. This paper discusses our initial implementation of VTAssist and reports on preliminary evaluation results. Our results indicate that our system can help wheelchair users to better understand and navigate around environments.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces -*Evaluation/methodology, User-centered design*; H.5.4 [**Information Interfaces and Presentation**]: Hypertext/ Hypermedia – *Navigation, User issues*

General Terms
Design, Human Factors, Verification.

Keywords
Location-aware, wheelchair navigation, location feedback, notification systems, mobile devices

1. INTRODUCTION
Mobile computing technologies are increasingly integrated in our daily lives, providing us with valuable information and services. However, there is a large group of people in our society with impairments whose needs are not being addressed by present technologies. The U.S Census Department reports that 19.3% of the country's population is disabled; the physically challenged group is the largest disabled group [17]. The everyday experience of disabled user groups can be hugely improved by systems that provide assistance specific to their abilities and needs.

Users with mobility impairments often have trouble accessing and navigating through locations because accessibility of those locations can change over time. For instance, an automatic door may malfunction, or a bathroom stall that was previously certified for the handicapped may no longer be accessible due to a newly installed sink. If users are notified about these changes, it improves their ability to safely navigate around locations and buildings.

In this paper we will discuss our location-based notification system, VTAssist: developed to assist users with mobility impairments to better navigate around the Virginia Tech campus by providing location critical information that would assist in planning short trips between and within buildings. This information is provided by coupling 2D maps and a feedback system accessed from a handheld device. The system integrates a location-aware web service seeVT, that was developed by a student research group for the Virginia Tech campus [14].

Our feedback system is driven by a platform-dependent collaboration from users of the system, who detect infrastructure changes and post it as feedback for the benefit of other users. Notifications are generated from these feedbacks to alert users of location status changes. To view and familiarize with the environment and identify location attributes such as entry/exit and elevator points, we have developed a map feature that displays the *location system* – a collection of accessible services that a building floor provides.

VTAssist was developed in collaboration with our client: the Assistive Technologies Lab at Virginia Tech, whose interests lie in creating and helping with technologies that are built to provide assistance to the disabled. The Assistive Technologies Lab has a history of sponsoring such research efforts, most notably a system where people with special needs use laptops that leverage wireless networks to show the location of accessible entrances and facilities relative to current position [2]. Our system was developed using a combined process derived from Scenario Based Design (SBD) and Extreme Programming (XP) to ensure that the system is developed efficiently and is highly usable.

Our system was evaluated by domain experts to test for usability and assess the value the system features added to users with mobility impairments. Our results are based on responses to user tasks during evaluation.

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2. BACKGROUND AND RELATED WORK

Mobile technologies are often developed to supply information to a user while he or she is engaged in a primary task. For example, a user might use a vehicle navigation system to get route information while driving. These *notification systems* are ideal for delivering critical information in a timely and effective manner in these multitasking situations [8][9]. The development of these systems does not typically consider the needs of people with mobility impairments. However this user group can derive benefits from such systems. In this section, we give an overview and background information of existing assistive technologies.

2.1 Assistive technologies

The field of assistive technologies is certainly rich with many developments that improve the lives of wheelchair users on a global level. However, most of the widely used technological advances providing location-specific information and way finding in location-aware systems for the disabled have been fully integrated into the wheelchair itself, limiting the user pool, and typically do not provide up-to-date information about the accessibility of the location.

Users entering unfamiliar locations need information of their physical environment for navigational support to decide and comprehend accessibility. Most buildings are designed to accommodate users with mobility impairments; however, they do not necessarily provide for all mobility issues. One common issue wheelchair users encounter that arose during the meetings with the Assistive Technologies Lab is the problem of finding correct information on location attributes within the Virginia Tech campus; for example, a door might not be wide enough for wheelchair entry. It is for these reasons that the wheelchair accessible sign does not always indicate a facility accessible to all wheelchair users. It is the objective of the system to notify users with augmented information on these location attributes.

Traditional solutions to location-based mobility assistance have been geared towards short-term navigation, and do not consider the problems of way finding and providing infrastructure information, especially in unfamiliar environments. One such system created in the field was the Smart Wheelchair Component System (SWCS), developed by Richard Simpson et al [15]. The SWCS detects obstacles with extra equipment built onto a powered wheelchair and take actions such as arresting movement and decreasing the turning radius. However, it does not provide a viable path, or information on the destination. Systems like the SWCS are not useful if the user can get to a location, but are not able to use the facilities due to lack of up-to-date information. Similar systems, such as the Semi-Autonomous Wheelchair with Helpstar [16] provide more information to the user of the surrounding environment, and even present options to the user for navigation. These systems also do not provide information on the infrastructure of the area, or the destination. A good navigational system should incorporate current destination information.

2.2 Location aware and navigation technology

Providing information of the surrounding environment is a primary goal in developing location-aware systems. The HCI Lab at the University of Udine has developed LAMP3D, a system for the location-aware presentation of real world content on a pocket PC [4]. Lamp3D utilizes a virtual 3D environment that correlates directly with the real world around the user. The user is then able to select the virtual object and extract detailed information on landmarks in a self-guided tour atmosphere. Choosing information of the surrounding environment to be displayed is important on a handheld given the limited screen space. This approach demonstrates the power of location-aware handheld devices. Wheelchair users can similarly benefit from a system that provides a map presentation, and allows selection of what information is to be viewed.

Peer-to-peer feedback has long been a useful tool in all aspects of life. By utilizing the experiences of one individual, many may benefit. A good example of this is the Relevance Feedback study conducted by Cornell University [3] . They found that when a user provides feedback on the relevance of query results future users get more relevant results for their queries. It is important to take advantage of peer feedback, as concerned users will provide the best information to other users since they are stakeholders themselves.

3. METHODOLOGY

VTAssist was designed using an agile development process based on Scenario-Based Design and Extreme Programming. This allowed us to develop usable systems in an efficient manner because the process was highly iterative, focused on constant communication with the client and allowed us to accommodate changes at all stages of the development process.

Combining the methodologies of Scenario-Based Design and Extreme Programming gave us a framework of being user-centric and focusing on usability issues. Extreme Programming creates a focus on good software engineering practices while being able to involve user views and needs. It rests on values of simplicity, communication, testing, and aggressiveness [1].

Scenario-Based Design uses scenarios which are narratives of users interacting with system features. Claims—which describe the positive and negative psychological effects of system features, were then extracted from the scenarios. An analysis of these claims allowed us to evaluate and discuss critical aspects of the design throughout the development process [12] .

It was decided early on in the development of VTAssist, that the Leveraging Integrated Notification Knowledge through Usability Parameters (LINK-UP) claims database would be used. The LINK-UP system provides continuous and integrated access to the design knowledge repository of claims, facilitating reuse of existing usability knowledge [6] .

In accordance with the needs of Extreme Programming we followed two week development cycles that allowed us to efficiently develop core features first, before moving on to higher level features.

4. SYSTEM DESIGN

VTAssist was designed to provide key features to provide location critical information to users with mobility impairments. One of the key problems for this user group is a lack of information on specific areas, or points of interest, on resources within buildings. Change of service status to points of interest could also entail larger problems for users, since they would need to find alternate locations or routes. This would be troublesome since they might need to backtrack toward an alternate location. To avoid these issues, we have added informational features to our system that not only provides static information on points of interest, but also provides notifications in response to feedback.

4.1 Our Client – Assistive Technologies Lab

The design of VTAssist was developed with continuous collaboration, contribution and communication with our clients at the Assistive Technology Lab at Virginia Tech. This was useful, as understanding the abilities and needs of our user group was important. Our clients understood the needs of our user group very well and worked collectively to explain them to us and collaboratively build features to satisfy those needs. We worked with them on two-week iterative cycles refocusing and building on features.

4.2 Key System Features

We will be viewing our system through the IRC framework - a classification for notification systems in which three critical parameters, interruption, reaction and comprehension, are considered. These serve as design goals and guidelines for the development of notification systems and determine how *interruptive* the system is to the user, whether the system supports efficient and accurate *reaction* to notifications, and how well users are able to *comprehend* and understand information provided by the system [9]. Our features are designed on a platform to notify users with information that help them decide to access locations of interest while taking their abilities into account. For example, a ramp that is accessible for an automated wheel chair user is not accessible for a manual wheelchair user.

Figure 1 – Main menu. Users may choose to view information on the facilities such as entry/exit points

4.2.1 *The Environment*

A user entering a new environment often wants to get familiar with their location and to identify accessible services that the location provides. This feature calculates the user's location and provides a map that familiarizes them with the environment. They could also view points of interest by request. Since we are providing familiarization on the locality mainly through the aspects of a map, we wanted the comprehension on the system to be high and the interrupt and reaction to be low.

Environments have various attributes that characterize the location-system. Attributes like entry/exit points, elevators, restrooms, and classrooms are of specific importance to users in a campus building. Users generally familiarize themselves with their environment by meandering through it on a need basis, which usually takes a lot of walking around. This is not the best method to adopt for disabled users, and not a very efficient method for general users. Location information is difficult to convey accurately through dialogue, resulting in ambiguity and misunderstanding [13].

To save time, energy and precision, we have facilitated a mapping scheme of building floors on the Virginia Tech campus to be viewed comprehensively on handhelds. When users request to "Get Location" their present location information is taken to pull up the floor map (see Figure 1). This map image is focused to a range of a few rooms, so that the user is able to comprehend his or her present location. To get a more complete feel of the location, the user can scroll around to view the floor and other points of interest (see Figure 2).

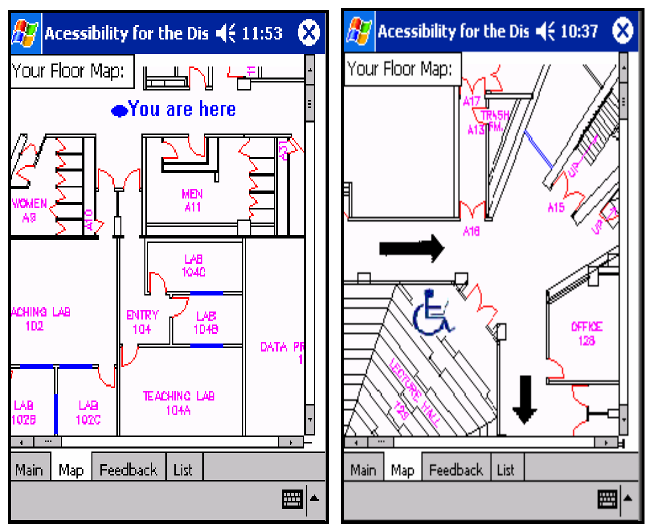

Figure 2 – A map feature gives the user orientation

The map feature also allows users to view requested points of interest. To do this the user can select the attributes provided by the drop down menu on the main tab. Selecting an attribute displays the point of interest on the map which can be traced back to the user's location with navigational arrows. This not only creates a notion of directional association to the user's present location but also provides the path the user should consider while accessing the location.

To identify attributes that VTAssist presents for users with mobility impairments on a map, we have associated the universal wheelchair accessible sign with rooms that provide wheelchair accessibility. This sign creates a good comprehension of points of interest for our users.

Coupled with the feedback notification features, the system is able to provide comprehensive decision making information for considering accessibility and path movement.

4.2.2 *Location Based Feedback Notification*

Points of interest in a building floor can be very dynamic in its service offerings for users with mobility impairments. To sketch a scenario: a user might be able to access a restroom, but while coming out faces a situation in which he cannot open the door as the automated open button has failed from the inside. These scenarios are not obstacles to regular users, but can create a troublesome situation for disabled users. To prevent users from facing situations while accessing points of interest we have developed a feedback notification system that records changes made to attributes and notifies users of these changes.

The feedback page operates much like a wiki, organized as location-based pages (see Figure 3). As changes are made to the pages, all users subscribed to the page are notified of the change, and are allowed to view the feedback on the location to understand the change, and consider how it affects them.

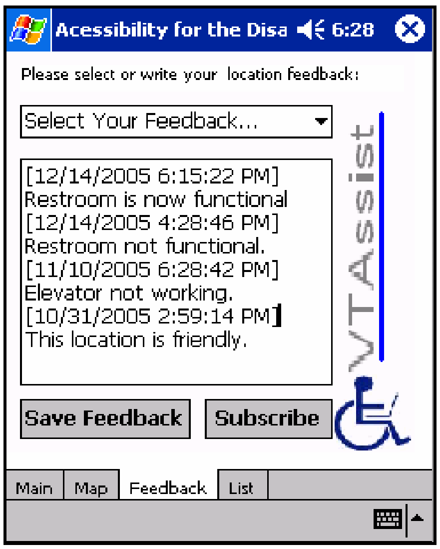

Figure 3 - The structure of the location feedback wiki.

These feedback pages can be edited by any individual present at the location, each change is located with a time stamp on it. The structure of the information can be changed by anyone, but by default it is set to keep the most recent updates at the top. Since it is very important for the feedback system to work on a collaborative basis, we needed to adopt a system that would facilitate users to share information. It is seen in an open-ended wiki based system over half the users contribute content [5].

The feedback offers a decision framework for navigation that, when coupled with aspects of notifications, can be very effective for efficient and helpful accessibility decisions.

Users can subscribe to location attributes for notification of changes that are posted (see Figure 4). Any change that is recorded by a user is delivered to users that are subscribed to the attribute. This helps regular or critical users of the attribute to seek alternate locations for services that have been disabled or are in a limited service rendering stage.

Users might want to save and remove their notification subscription on location attributes. This needs to be very quick and easy to manage, since the user's need to track feedback changes on points of interest could be temporary and have a large range. For this purpose, our notifications manger is based on a tree view that we felt could be easily traversed and understood. Many of the attributes act like internal nodes that are superfluous, and trees significantly save space by eliminating the superfluous nodes [7].

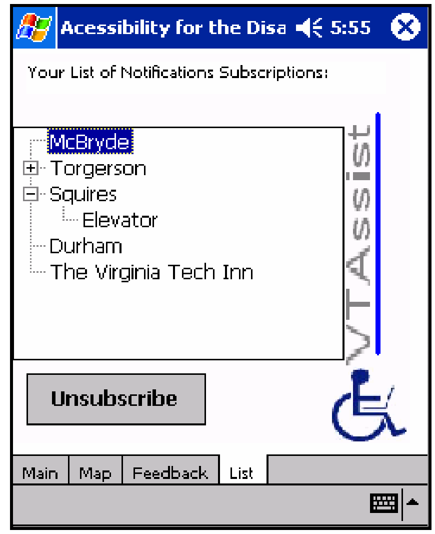

Figure 4 - List of Notifications the user is subscribed to.

Emergency – It is widely noted that during a fire emergency there is a shortage of guidance towards individuals with disabilities. Disabled residents are considered to have the highest death risk [10].The New York Fire Department has published protocols for the physically challenged to follow during emergencies, or has procedures to identify in advance individuals that need assistance [11]. We believe that the feedback notification system can be used to deliver critical information during an evacuation emergency sensitive to the user's location.

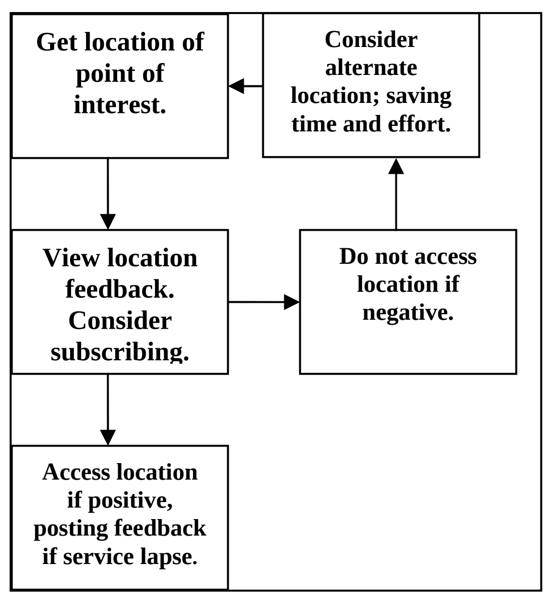

Figure 5 – Task Flow of a user; not considering notification.

4.3 The task flow – How it would be used

The main menu guides the user to other tabs and windows that render assistive information. Figure 5 shows a detailed flow of how a user would go about requesting and using information.

4.4 Implementation

VTAssist was designed to be used on a handheld device. Handheld devices are ideal for applications that are synchronous and collaborative in nature, being able to connect to networks at different places and accessing geographical context-driven information [13].

For facilitating greater development opportunities we adopted the pocket PC by Microsoft, which gave us the option of developing the application on C# in the .NET framework. The web service functionality that .NET provides was a major contributor to the decision.

5. EVALUATION

VTAssist was evaluated by two domain experts at the Assistive Technology Lab. The evaluation is based on the responses to our questions derived from tasks that were given to users to perform.

Task	Expert Opinion 1 (easy) – 5 (hard)
View Location and feedback	1-2
Post New Feedback	1
Notification Management	1
Notification Comprehension	1
Overall Effectiveness	2-3

Table 1 –Wheelchair user expert opinion on usability

The first task mainly required the user to be able to identify the location and be able to browse the map and get a feel of the environment and seek information by understanding the map or asking the system to identify points of interest; the user would later access the feedback system to decide on accessibility. User results showed that the system could be easily used to identify locations and help familiarize the user with the location system. This was very important since users seeking information on location attributes are largely new to the environment. Results indicated that users will be very comfortable in finding attributes and will be able to associate their current location to the point of interest. This tested the systems ability to help users navigate between points; handheld computing gives the ability to constantly refer to a map for navigation.

The environment mapping feature provided by VTAssist could be used to familiarize and guide users to points of interest. Users reported this was easy to use and helped navigation. Though familiarization and identification was high, users felt the need to be able to zoom in and out of map views, and be able to view locations at a larger scale would be helpful.

Task 1 later required the user to get attribute information from the feedback feature, and use the questionnaire in deciding whether the information helped them make a better decision in accessing the location. This was designed to understand the usability of the feedback system. Results showed that users found the feedback system to be very convenient to access information, this was very important to the feature, since information needs to be structured well, easy to view, and comprehensible.

Since VTAssist is a collaborative system based on the feedback users provide on location attributes, users needed the ability to provide feedback easily and quickly. Task 2 required the user to navigate to a location and find a change in service status that they were required to post to the feedback system. For a quick post we had included a list of service entries that we anticipated users would most likely post. Users found the feedback system very easy to post their messages; this result was promising since the system needs active user posts to be able to generate helpful up to date notifications for all users.

Tasks 3 and 5 were designed to get usability feedback on the notification manager. This is of concern to users that want to monitor varying locations on a daily basis. This feature had extremely positive ratings from users; the tree structure presents attributes specific to their location, and provides an easy way to select and unsubscribe to notifications.

The overall system rating of VTAssist was very promising and users felt that the information the system provided was useful in determining their decisions to access locations, and the map assisted in navigation. Users were concerned about the collaborative dependency of the system, and were worried about the system being up to date. They felt that the system would help users save time and become more efficient. Many users wanted VTAssist to provide fire exit and water fountain points as well. The ability of VTAssist to run on a tablet pc was recommended, as wheelchair users could navigate while having a larger secondary/supportive view on the tablet pc.

6. DISCUSSION & CONTRIBUTION

VTAssist was an endeavor to create a notification system that provided critical information to mobility-impaired users for accessing locations of interest. The process we have discussed involves understanding the information needs of users with mobility impairments, and turning those needs into a system responsible for gathering and delivering up-to-date location information. We found that the system would be beneficial as a heuristic navigation system. This would need a well integrated mapping system that identifies key locations.

The agile scenario-based development process gave us an engineering platform that helped to manage and understand requirements, while we continued to aggressively create the basic foundations of the system. The iterative development cycles created a time frame for development that brought focus and agility.

We hope to foster awareness of the needs of disabled people in the fields of notification systems, information systems, and assistive technologies and encourage the creation of novel technologies that address their needs through the incorporation of new technology such as ubiquitous computing systems and Wi-Fi networks.

7. CONCLUSIONS & FUTURE WORK

VTAssist currently delivers information to users with cognitive abilities to read, view, and understand the information presented on a screen. This restricts the system's ability to help users with other disabilities. Our future endeavors will add voice and text driven interfaces with the system. This was taken into consideration while building the system, by keeping input needs low. We plan to work further with the Assistive Technologies Lab to identify critical information content for users that have other impairments.

Our current stable of features can be expanded to provide many more critical services. A problem for users with low navigation abilities is entering areas that can be dangerous such as construction areas. To solve this problem we plan to build a zone notification feature that is able to detect the user's position constantly and warn them of entering a zone that is seen not fit to their abilities.

We plan to incorporate an "Emergency Help" request option that is already in the development stages, which will be associated with organizations that can provide emergency assistive services. The help option would ask the user to identify the kind of help he or she needs, and accordingly alert the appropriate organization of the user's location for help. To provide this, we need organizations to agree to this service.

We will also focus on developing the map features to better present information on the location system. We will consider developing a version for the TabletPC, since it provides better viewing abilities and can provide a good supportive view while users navigate their wheelchairs.

The results we received from the evaluation were very promising, and we hope to continue our work on VTAssist to help more users. This will help to build the collaborative environment that is essential to the success of VTAssist.

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9. REFERENCES

[1] Beck, K., *Extreme Programming Explained: Embrace Change*, Addison-Wesley, Reading, Massachusetts, 1999.

[2] Bowen, C. L., Buennemeyer, T. K., Burbey, I., and Joshi, V. Using wireless networks to assist navigation for individuals with impaired mobility." *Proc. of the 21st Annual Technology and Persons with Disabilities Conference*, 2006, to appear.

[3] Buckley, C., Salton, G., & Allan, J. The Effect of Adding Relevance Information in a Relevance Feedback Environment. *Proc. SIGIR* (1994), 292-300

[4] Burigat, S. & Chittaro, L. Location-aware Visualization of VRML Models in GPS-based Mobile Guides. *Proc. 3D Web Technology* (2005), 57-64

[5] Chau, T. & Maurer, F. A Case Study of Wiki-based Experience Repository at a Medium-sized Software Company, *Proc. Knowledge Capture* (2005), 185-186

[6] Chewar, C. M., Bachetti, E., McCrickard, D.S., & Booker, J. Automating a Design Reuse Facility with Critical Parameters: Lessons Learned in Developing the LINK-UP System. *Computer-Aided Design of User Interfaces* (2004), 236-247

[7] Fiala, E. R. & Greene, D. H. Digital Compression with finite windows. *Communications of the ACM*, April 1989, 32, 4, 490-505

[8] McCrickard, D. S., Chewar, C. M., Somervell, J. P., & Ndiwalana, A. A Model for Notification Systems Evaluation--Assessing User Goals for Multitasking Activity. *ACM Transactions on Computer-Human Interaction*, December 2003, 10, 4, 312-338

[9] McCrickard, D.S. & Chewar, C. M. Attuning Notification Design to User Goals and Attention Costs. *Communications of the ACM*, March 2003, 46, 3, 67-72

[10] Miller, I. & Beever, P. Victim behaviours, intentionality, and differential risks in residential fire deaths, *WIT Transactions on The Built Environment* (2005), 82

[11] New York Fire Department. Office Building Emergency Action Plans. Notice of Opportunity to Comment on the Proposed Promulgation of 3 RCNY, 6-02

[12] Rosson, M. B., Carroll, J. M. *Usability Engineering: Scenario-Based Development of Human-Computer Interaction*. Morgan Kaufman, New York, NY, 2002.

[13] Roth, J. & Unger, C. Using Handheld Devices in Synchronous Collaborative Scenarios. *Personal and Ubiquitous Computing*, December 2001, 5, 4, 243–252

[14] Sampat, M., Kumar, A., Prakash, A., McCrickard, D.S. Increasing Understanding of a New Environment using Location-Based Notification Systems. Poster paper in *Proceedings of 11th International Conference on Human-Computer Interaction (HCII '05)* , Las Vegas NV, July 2005

[15] Simpson, R., LoPresti, E., Hayashi, S., Nourbakhsh, I., & Miller, D. The Smart Wheelchair Component System, *Journal of Rehabilitation Research & Development*, May/June 2004, 41, 3B, 429-442

[16] Uchiyama, H., Deligiannidis, L., Potter, W.D., Wimpey, BJ, Barnhard, D., Deng, R., & Radhakrishnan, S. A Semi-Autonomous Wheelchair With HelpStar. *Lecture Notes in Computer Science*, June 2005, 3533, 809-818

[17] Waldrop, J., & Stern, S.M. Disability Status: 2000, *Census 2000 Brief.* US Census Bureau, March 2003