Utility of a Mobile Route Planning App for People Aging with Disability

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Abstract* - Mobility is a key contributor to an individual's community living and participation. As a result, outdoor environmental barriers, such as uneven sidewalks and no curb cuts, play a crucial role in the development of disability and loss of independence among individuals aging with mobility and vision limitations. To compensate, people with disabilities typically plan routes before going out. However, they often lack the appropriate street-level information about the environment to plan routes that meet their abilities and needs for safety and accessibility (e.g., the location of curb cuts and crosswalks). As a result, the real impediment to outdoor mobility is not the actual barriers, but the lack of information about those barriers for route planning. To provide the street-level information about barriers that would maximize the independent living and community participation of people with mobility disabilities, the project team developed a working prototype of the Application for Locational Intelligence and Geospatial Navigation (ALIGN) based on static graphical information systems (GIS) data (e.g., physical infrastructure, slope, crime rates and land uses). This study details the utility testing of the application with individuals aging with mobility and vision limitations by using direct observation, think-aloud and open-ended questionnaires. Findings indicate that participants found the application to be potentially useful, especially in unfamiliar locations. However, testing also indicated a number of refinements, including multimodal input and outputs that would enhance the utility of the initial prototype. Additional design criteria will inform the next prototype, including use of consistent audio/visual feedback, and simpler directions. These criteria will be applied to create a more usable application for the target population.

Keywords-mobile wayfinding; assistive technology; aging in place.

I. Introduction

From the need for basic exercise, to more complex participatory behaviors, such as grocery shopping, going to the doctor and visiting friends, mobility is a key contributor to an individual's community living and participation. For older adults and individuals with disabilities, outdoor mobility is especially important to successfully to maintain independence, physical and mental health, and quality of life [1][2]. Not surprisingly, outdoor environmental barriers, such as uneven sidewalks and no curb cuts, play a crucial role in the development of mobility disability among individuals with a range of functional limitations [3]. Whereas removing physical barriers in the U.S. has been ongoing for more than a quarter century since the passage of the Americans with Disabilities Act in 1990, it is an expensive and long-term process that will likely continue for many years to come.

To compensate for environmental barriers, people with disabilities typically plan routes before going out [4]. Community activities are organized in advance to formulate strategies that address, for example, the inaccessibility of routes, distances travelled and terrain. However, the appropriate street-level information about the environmental attributes (e.g., the location of curb cuts and crosswalks) that are needed to plan routes that meet an individual's own abilities and needs is often lacking. As a result, the real barrier to outdoor mobility may not be the actual environment itself, but the lack of information that would empower individuals with mobility impairments to plan safe, accessible and situationally-appropriate routes based on their own abilities, needs and preferences.

Whereas creating totally barrier-free environments is an ideal goal, providing environmental information for individualized route planning is a comparatively inexpensive and short-term process that could immediately impact community mobility for seniors with a mobility disability. To provide the type of street-level information about barriers that would maximize the community mobility for these individuals, the project team developed a working prototype of the *Application for Locational Intelligence and Geospatial Navigation* (ALIGN) based on static graphical information systems (GIS) data (e.g., physical infrastructure, slope, crime rates and land uses). This paper reports on the usefulness of the application in providing mobility assistance to people aging with vision and ambulatory limitations.

The second section of this paper details the current practices of and barriers to pedestrian mobility, as well as the available resources to help with travel route decision-making. Section 3 describes the prototype design, and the research methods used to test the application's utility. The results outlined in Section 4 give insight to the errors made in observation of route navigation, in addition to the post-trial questionnaire responses. Finally, Section 5 discusses the implications of these results and recommendations for the application's next iteration.

II. Background

Community mobility is both a means and an end. As a means, it is a way to get from one place to another. As an end, it is an activity that is the most commonly reported form of physical activity that has demonstrated a variety of health benefits [5]-[7].

Despite the positive impact of environmental facilitators, such as curb cuts, tactile warnings and audible pedestrian signals, people with disabilities routinely encounter difficulties while either "walking" or "wheeling" in their communities, even on routes that are "accessible" under the 2010 Americans with Disabilities Act Standards for Accessible Design [8]. Barriers not covered in the standards (e.g., long distances, steep slopes, high curbs, wide streets and short traffic lights), can deter traveling in the community, thus compromising health, independence and overall quality of life.

Numerous studies have linked restricted community mobility among people with disabilities to the wide range of barriers and hazards, many that compromise safety (e.g., crossing a busy intersection) and increase fatigue due to maneuvering around obstacles (e.g., a pole in the middle of a sidewalk). Specific barriers identified in the literature include: curbs, lack of curb ramps, sidewalk availability, poor drainage, narrow pathways; hilly or steep topography; ramp availability, presence of crosswalks, availability of resting places and shelters, lack of accessible parking, presence of water fountains, bathrooms, and rest areas; unsafe neighborhoods, and inclement weather [2][3][9]-[13].

Individuals with disabilities generally use familiar outdoor routes that fit their functional abilities and assistive technologies. However, for those who are experiencing the additive effects of age-related declines, environmental barriers continually pose new sets of challenges that can further limit mobility even on long-used routes [14][15] leading to mobility restricted participation in multiple activities outside the home [16]. In fact, limitations in walking for exercise is secondary to restricted access to a variety of community destinations, including grocery stores, senior centers, drug stores and places of worship [17]. Most importantly, these restrictions not only lead to further decline in function, but also have broader implications for nutrition, medical care, and other community services that are crucial to independence, social connectedness, health and well-being of seniors with disabilities.

To aid pedestrian route planning, many navigation apps, such as *Google Maps, Co-Pilot, Mapquest and Waze*, have walking functions that provide voice-guided turn-by-turn directions similar to their driving functions. In addition, there are a growing number of mobile applications that are intended to promote walking by assessing the pedestrian friendliness of an area and translating this information into a walking score. Most (e.g., *Walkscore.com, Walkonomics.com* and *Walkshed.org)* provide information about environmental factors, such as access to amenities, residential density, street connectivity, land use diversity, traffic safety and crime safety that influence walking behavior and route decision-making [18][19]. Whereas many of the attributes included in these applications are relevant to people with mobility disabilities, few, if any, of the applications include the environmental characteristics that would address the specific needs of people with aging with mobility disability.

Similarly, there are a growing number of mobility applications for individuals with disabilities. Among these, *Rollstuhlrouting* (wheelchair routing) is the only online application that includes environmental factors to inform route planning for wheelchair users. However, this portal uses only 3 infrastructure parameters: slope (4% – 12% in 2% increments and any slope), surface material (4 types) and curb heights (3cm – 11cm in 2cm increments and any height) that are deemed necessary for wheelchair accessible routes. Two newer applications, *IBM Accessible Way* and *PathVu*, use crowd-sourcing approaches to gather street-level accessibility information, such as mobility barriers, poor sidewalk conditions and absence of lighting, tactile paving, curb ramps, and crosswalks. However, these applications are not only dependent on volunteer data, which has implications for the reliability of the data, but are also focused solely on wheelchair accessibility, which limits their generalizability to people aging with various disabilities. Environmental features that are perceived as safe and accessible by one individual may be viewed very differently by individuals with different functional abilities, preferences, motivations, support systems and tolerance for risk.

Most importantly, decision-making about travel routes tends to be situational and idiosyncratic, unique to individuals and to a particular point in time, and often dependent upon an individual's ability to make an accurate assessment of the accessibility, safety and desirability of a route. To do so, the main challenge is to obtain environmental information that individuals do not have in order to identify and potentially avoid routes that include environmental barriers, as well as to factor in other situational variables, such as time, distance and safety. Without such information, the most expedient solution is to avoid traveling in the community altogether, which partly explains reduced levels of activity and exercise among seniors and people with disabilities.

To overcome limitations in the existing walkability and accessibility applications, the project team developed ALIGN, a mobile route planning application that not only considers the salient physical environmental factors that impact accessibility and safe mobility, but also an individual's personal and social motivations and preferences that influence route planning. Most importantly, based on an array of essential and secondary user preferences, ALIGN not only prioritizes alternative routes, but also identifies the location of potential barriers where routes do not meet user requirements. This paper reports on the initial prototype testing to evaluate its usefulness by people aging with disability prior to full-scale deployment and testing.

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III. METHODS

A. Research Design

The study used a mixed methods approach in an outdoor setting to determine the usefulness of the application. This included direct observation of the application in use, thinking out loud to record participant feedback during app use and post-test questionnaire to obtain user feedback about the application. Direct observation of participant behavior while completing a series of routine tasks (e.g., select parameters, input a destination, choose a route, follow the route) enabled the study team to record objective data about errors made including difficulty finding the correct buttons and avoidance of the 'problem area' icons in the laboratory usability study, veering off course outdoors, backtracking, pausing/confusion, and wrong turns on the outdoor route. Thinking out loud provided opportunities to obtain subjective participant experience about underlying problems that were not evident or had to be inferred from direct observation (e.g., confusion, how often they would like audio/visual feedback). Similarly, post-test questionnaires, provided an opportunity for participant feedback through a series of questions with Likert scale levels of agreement (where 1=strongly disagree to 5=strong agree) and open-ended questions about the usability of specific features of the application, as well as their overall impression of the application. Questions were used to gauge how participants felt about the application's potential, and where there were subjective errors and room for improvement.

B. Prototype Test Application (ALIGN 1.0)

ALIGN is built on: 1) environmental factors based on existing walkability and accessibility literature that are applicable to route planning decisions by individuals with mobility disabilities; 2) a database structure and data acquisition processes to import the validated factors; 3) a weighting system applied to each factor based on an Analytical Hierarchy Process (AHP) that generates mobility scores for route segments; 4) implementation of a routing algorithm; and 5) a simple and intuitive user interface based on universal design principles.

The prototype application (Fig. 1) enables users to select from a number of mobility factors, including accessibility factors (e.g., slope, presence of curb ramps) and other static

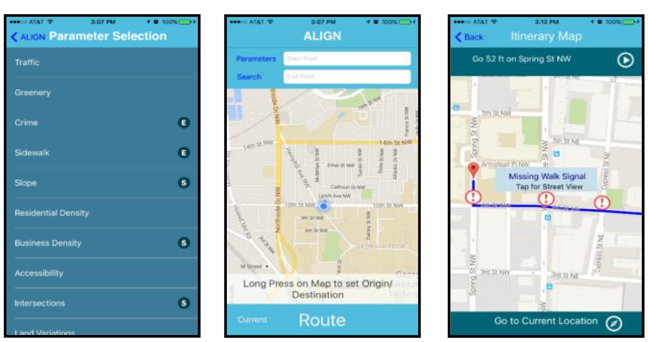

Figure 1. Prototype screenshots of the parameter selection page, the map landing page, and a sample route showing parameter errors

infrastructure factors (e.g., land uses, vegetation, street connectivity) based on their own needs and desires. A variety of readily available GIS sources were used to automatically capture much of the environmental data. As a result, ALIGN databases and algorithms are updated at the same time as the original sources. We used the street network data from 2007 Georgia Dept. of Transportation and the Atlanta Regional Commission street file. Block boundary data were obtained from 2010 U.S. Census Bureau TIGER/Line shape files. A measure of intersection density was calculated using the ArcGIS network analysis tool based on the street network data. The variables in the residential density group were calculated using the ArcGIS operator tool based on the 2010 U.S. census block data. Similarly, the variables in the business density, land use mix diversity and land use mix accessibility categories were calculated using the ArcGIS operator tool, zonal analysis tool and Euclidean distance tool, based on the 2012 reference USA business database. Crime data were obtained from the Atlanta Police. Slope was calculated using the ArcGIS 3D analysis tool, based on the 1999 digital elevation model data (30 meters pixel resolution) provided by the U.S. Geological Survey (USGS). ERDAS 9.3 Indices tool was used to quantify vegetation coverage based on the 2011 Landsat image data provided by the USGS. Traffic volume was obtained from the 2009 average annual daily traffic data provided by the GA Department of Transportation (GDOT). Public transit data were collected from the 2010 GA Regional Transportation Authority. Finally, sidewalk data were obtained from the GDOT.

A number of key environmental factors were not available in any systematic GIS dataset, including the presence of curb cuts, crosswalks, traffic signals and intersection type. To capture these types of data, a data collection protocol was developed to capture and record environmental features of interest directly from *Google Streetview*.

Ideally, the ALIGN mobile application would be able to create routes that cater to all possible combinations of essential environmental factors (referred to henceforth as parameters). However, in most cases, it is unrealistic that any nearby route would be able to fit all criteria. Thus, a maximum of five essential parameters (and unlimited secondary parameters) can be selected in order to create a useful tool that allows users to be able to choose the parameters that are essential for their walking routes, for their flexibility, as well as their safety.

C. Test Environment

Three routes were laid out at the eastern edge of Georgia Tech's campus and extending into the adjacent neighboring community of Midtown, Atlanta. All three routes (Fig. 2) had the same starting point. However, each route had a different destination and the numbers and types of potential mobility barriers. The destinations varied in length and complexity. The simplest (to Starbucks 1 on the map) was one block and included crossing a street with a missing walk signal. The second route was two blocks (to Starbucks 2) without any potential mobility barriers. The third route was three blocks (to the Center for the Visually Impaired) and included an intersection with no crosswalk or traffic signal.

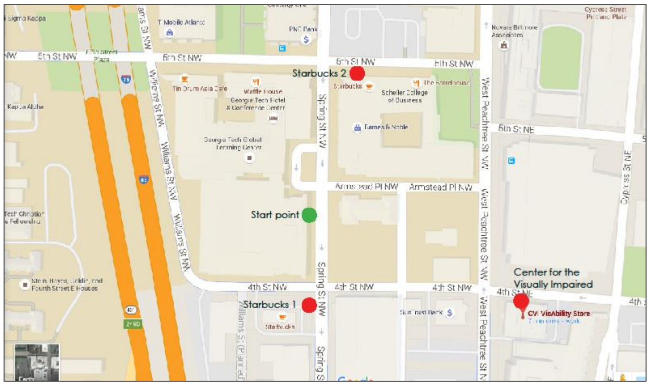

Figure 2. Map of observation routes

D. Procedures

After consenting to participate in a test protocol approved by the Georgia Tech Institutional Review Board, participants were given the ALIGN application on a mobile device. All participants were given the same minimal description of how to use the application so as not to bias its use. Participants were instructed to complete two of three test routes, selected at random. A researcher walking along with the participant recorded errors made including: veering off course, backtracking, pause/confusion, and wrong turns. Each error was noted as 'self-corrected' by the participant or 'team-corrected' by the researcher. It was also noted where participants asked for help and when it was provided. Following each trial, participants were asked to provide their level of agreement (on a 1-5 Likert scale where 1= strongly disagree to 5 = strongly agree) with items regarding the usefulness of the app.

IV. RESULTS

A. Sample

Thirteen (13) individuals 50+ years of age with a self-reported ambulatory and/or vision limitation for at least 5 years that affected their mobility in outdoor environments were recruited for the study. Participants were recruited from local retirement communities, as well as three GA Tech participant registries: HomeLab, a registry of over 500 seniors who have agreed to participate in in-home and community studies; the CATEA Consumer Network, a registry of adults with disabilities; and the TechSAge Registry, a registry of older adults with disabilities.

Of the 13 participants included, three were men and ten were women. Seven participants had some degree of vision loss and eight had some degree of mobility impairment with two participants reporting having both vision and mobility limitations. Subjects ranged in age from 50 to 76 years of age, with a mean age of 63.8 years. Education levels varied amongst the participants – two had vocational training, four had some college or associate's degree, two had received bachelor's degrees, one had a master's degree, and two participants had received PhDs.

B. Observation Data

Table I shows the observed and stated errors during the outdoor observation route. Some participants made repeated errors, which are noted accordingly in the overall number of instances (i.e., 10 participants paused on their route 17 times total on their collective routes). The results are spread more or less evenly across demographics, with the exception of the two low vision participants who veered off-course.

Of note, 9 participants missed or did not recognize their destination, which can be attributed to the lack of a visual or audio notification that they had arrived at their destination. Similarly, 9 participants who had warnings that the route had missing walk signals did not see or hear the warning.

Finally, half (n=5) of the participants paused at intersections to look at the application. Nonetheless, of the 17 times the 10 participants paused or were confused, all were self-corrected. In contrast, there were only 2 instances of wrong turns and 2 instances of veering off course and 3 of the 4 were self corrected.

TABLE I. OBSERVED ERRORS ON OUTDOOR ROUTE

	Pause/Confusion		**Wrong turn**		**Veering off-course**		**Help**		
	Self - corrected	*Team - corrected*	*Self - corrected*	*Team - corrected*	*Self - corrected*	*Team - corrected*	*Asked*	*Provided*	*Asked and provided*
Overall # of instances	17	0	1	1	2	0	2	2	8
Overall # of participants	10	0	1	1	2	0	2	2	5
Participants w/ low vision	6	0	0	1	2	0	1	2	3
Participants w/ low mobility	4	0	1	0	0	0	1	0	2
Participants< 65 years	5	0	1	0	1	0	2	2	2
Participants≥ 65 years	5	0	0	1	1	0	0	0	3

C. Post-Trial Questionnaire

Most notably, participants strongly agreed (mean = 4.58) that the mobility factors met their needs for route planning. In fact, when queried about the need for additional factors 11 of 13 participants did not see room for any additional parameters, while two suggested adding factors that are not necessary for safe mobility (i.e., accessibility of doors in buildings and nearby places to eat).

In response to the statement that the app would be helpful for navigating as a pedestrian, the mean response of 3.38, or slightly above neutral. In contrast, the mean response to the statement that it would be easier to navigate as a pedestrian with the application than without it was 4.0 or agree. However, when asked if they would use the app, six of the participants responded that they would use it, if it worked perfectly. In addition, 4 participants stated that the app would be easier to use once they were able to familiarize themselves with it.

Finally, when asked if there were any unexpected barriers in using the application, 10 participants provided recommendations for refinement, including: the ability to input location names (i.e., Publix) instead of only addresses; providing notification upon arrival at a destination and more feedback from the application as a whole; providing cardinal directions; user-friendly terminology; and reducing the learning curve when first using the app.

V. Conclusion and Future Work

Participants reported that, overall, the application was more beneficial than not. Moreover, it is likely to be used, if it is working properly and more user friendly. However, this will require refinements before the application is ready for prime time. Clearly, consistent participant feedback about the lack of auditory input and output, as well as noticeable route errors, such as missing the destination, suggest that there is need for consistent feedback to the user. While the prototype was tested prior to the implementation of these interfaces, the planned addition of voice control (e.g., voice command option on the map screen) and audio, visual and tactile feedback in v. 1.1 (e.g., audio feedback at turns and barriers) should increase usefulness and usability of the application. In addition, utility will be enhanced in v.1.1 by the inclusion of other participant recommendations including a tutorial when first opening the app, inputting location names, use of more user friendly terminology and option for cardinal directions.

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