The Blind Leading the Blind: Toward Collaborative Online Route Information Management by Individuals with Visual Impairments

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Abstract

The long-term objective of our project is to discover the fundamental principles underlying the collaborative production, sharing, and management of route information by travelers with visual impairments. The specific research hypothesis is two-fold: 1) people with varied levels of vision loss and orientation and mobility (O&M) skills will be able to form online social networks that collaboratively manage large route information collections for different geographic areas, and 2) members of such networks will be able to successfully travel through a variety of previously unknown indoor and outdoor environments of varied complexity when provided with online verbal route directions referencing landmarks and path integration information salient to their particular vision and skill level. In this paper, we report on the initial stage of our project: an online survey whose objectives are to collect samples of route descriptions from travelers with visual impairments and to do the initial profiling of the target population. The data collected so far provide valuable insights into what travelers with visual impairments need to know about their environments in order to travel independently and how they may communicate that information to their fellow travelers in the future.

Introduction

The adoption of the Rehabilitation Act of 1973 (U.S. Congress 1973) and the Americans with Disabilities Act of 1990 (ADA) (U.S. Congress 1990) provided legal and financial incentives for improvement in universal access (LaPlante & Carlson 1996). Many R&D activities initiated by the Acts focused on removing structural barriers to universal access: building ramps and bus lifts, developing specialized interfaces, e.g., haptic, Braille, sip and puff, to electronic and mechanical devices, and retrofitting auto vehicles for wheelchair access. These important pursuits have not removed the main functional barrier faced by people with visual impairments: the great difficulty of independently orienting to, and navigating through, dynamic and complex everyday environments. This barrier severely limits their ability to travel independently outdoors, impedes spontaneous use of public transportation, denies them equal access to buildings, and helps create conditions that cause this group to have one of the highest unemployment rates of all disabled groups (74%) (Kaye, Kang, & LaPlante 2000).

Much R&D effort has been dedicated to wearable assisted navigation solutions using various sensors including GPS (Loomis *et al.* 2005), infrared (Addlesee *et al.* 2001), radio frequency identification (RFID) (Ross 2001), and Wi-Fi (Kulyukin & Nicholson 2005). While these approaches have shown promise, they have had limited success due to the following gaps.

Gap 1: Inadequate Investigation of Route Sharing and Production by the Visually Impaired

It is well known that travelers with visual impairments share verbal route descriptions and traveling experiences with each other (Gaunet & Briffault 2005). The sparseness of the visually impaired population confines such interactions to routes in and around public transportation facilities or routes in and around agencies serving this population. Since routes around communities and local shopping malls are rarely in common, they are never discussed. This situation discourages exploration of new spaces and navigation to unfamiliar areas.

Another problem is that verbal route descriptions which visually impaired navigators share with each other and, more importantly, rules that govern their production have not been adequately investigated and formalized. The evaluation of the wayfinding devices typically takes place in very limited numbers of settings and under limited numbers of conditions. The selection of settings and conditions is unfortunately often determined for the convenience of the researchers, not by the concerns of the target population. Poor sales statistics of commercially available wayfinding products indicate that there may be some issues regarding the design of route instructions. They may also indicate that, if the routes are well described in a given environment, assisted navigation devices may not be needed at all, at least for some travelers.

Gap 2: Inadequate Profiling

The terms *visually impairment*, *blindness*, and *low vision* have multiple definitions that depend on the context in which the definition is given. There is a complicated continuum from total blindness to full sight. It has been shown that even a slight degree of vision, e.g., light perception, offers significant navigational advantages (Blasch & Stuckey 1995). Vision, however, is but one component of the traveler's profile. Travelers code locations, directions, and distances in terms of the information they have about the environment, prior knowledge, and their sensorimotor abilities. Mastering O&M skills is a life-long process. After receiving basic O&M training from professional O&M instructors, many individuals with visual impairments improve their O&M skills through independent navigation and acquire new wayfinding skills, thus changing their initial profiles.

Gap 3: Small Sample Sizes

Small sample sizes are a persistent problem in blind navigation (Blasch & Stuckey 1995). To some extent, they can be justified by the uneven distribution of the visually impaired population. For example, in the U.S., the majority of people with visual impairments tend to concentrate in a limited number of urban areas (LaPlante & Carlson 1996). The uneven distribution of the target population makes it very difficult for investigators to make statistically significant inferences. Small sample sizes have been a serious obstacle to studying the relationships between different types of visual impairments and the ability to understand and follow route directions.

Objectives and Aims

Many individuals with visual impairments now have Internet access. The web has many personal web pages of visually impaired travelers who discuss their traveling experiences in various geographic areas. Thus, the visually impaired community appears to be ready to develop electronic social networks for producing, sharing, and managing information pertinent to independent traveling.

Another trend is the increased presence on the Internet of websites and tools geared towards social networking and collaborative functionality. Websites and tools, such as Flickr, YouTube, and Wikipedia, allow users to create content, collaborate with one another, and organize and share information. On these sites, users are allowed and encouraged to contribute and manage the content, thereby increasing the amount of shared knowledge available to the community at large. Another feature of many of these sites it that they either provide application programming interfaces (APIs) or data downloads, allowing other users to analyze and use the data in ways not necessarily intended by the original designers.

Our long-term objective is to discover the fundamental principles underlying the collaborative production, sharing, and management of route information by travelers with visual impairments. The specific research hypothesis is two-fold: 1) people with varied levels of vision loss and O&M skills will be able to form online social networks that collaboratively manage large collections of verbal route descriptions for different geographic areas, and 2) members of such social networks will be able to successfully travel through a variety of previously unknown indoor and outdoor environments of varied complexity when provided with online verbal route directions referencing landmarks and path integration information salient to their particular vision and skill level. It should be noted that the first part of our hypothesis is formulated so as to include sighted travelers. Thus, our hypothesis is that sighted travelers will be able to collaborate with visually impaired travelers in managing verbal route information for various geographic areas.

The hypothesis rests on the considerable body of evidence reported in the blind navigation literature that independent travelers with visual impairments successfully share route knowledge with each other via spoken language (Gaunet & Briffault 2005). The two assumptions underlying this hypothesis are: 1) as an information delivery mode verbal route directions are easily affordable, accessible, and usable by many travelers with visual impairments; and 2) this mode avoids such common problems as the loss of GPS signals or the unavailability of geo-referenced digital maps.

The long-term specific aims are: 1) to create a large digital database of verbal route descriptions in different environments given by travelers with visual impairments; 2) to share the database with all interested communities; 3) to perform ontological and statistical analyses of obtained descriptions; 4) to validate the research hypothesis in double-blind navigation trials at various U.S. sites; and 5) to develop a online community service for visually impaired travelers.

We view aim 5 as potentially very useful for various visually impaired communities. Goodchild (Goodchild 2007) discusses the evolving area of Volunteer Geographic Information (VGI), user and community generated GIS tools, data, and websites. The problem with the current tools and websites is that they target sighted travelers, limiting their use by the visually impaired. We envision a VGI service where the community built map is not visual, but based on verbal route descriptions. Initial route descriptions may be submitted by both sighted and visually impaired travelers. Inadequate route descriptions will be collaboratively mended, filtered out, or replaced with new ones. Of course, traditional GIS data, such as GPS and compass data, may also be incorporated, but the core of the system would be based around route descriptions.

This paper focuses on primarily on aim 1 and, to some extent, on aim 2. It is our hope that understanding how visually impaired travelers relate navigational knowledge to each other will help us make more informed decisions about the generic functionalities of an online route information sharing service for the visually impaired. Our paper is organized as follows. In Section 1, we describe our online route description collection from the target population and analyze the respondent demographics. In Section 2, we present our route ontology. In Section 3, we present the results of our initial route analysis. In Section 4, we give our conclusions.

Route Description Collection

In August 2007, the Computer Science Assistive Technology Laboratory of Utah State University (USU CSATL) launched a web site with an online survey to collect real-world route descriptions from visually impaired individuals. The site's URL was advertised through the e-mail channels of the USU Center for Persons with Disabilities and the National Federation of the Blind (NFB) Utah Chapter in Salt Lake City, Utah.

Participation in this survey was completely voluntary. The web site did not collect any personal or identifying information, such as names, addresses, emails, SSNs, or any other identifying information. Nor did the web site use cookies to track users.

The survey consisted of two sections. The first section collected demographic information consisting of gender, age, education level, level of blindness, number of years the vision loss has impacted navigation ability, primary navigation aid, whether or not the participant has received O&M training, navigation skill level, and the presence of other disabilities in addition to visual impairment which may affect navigation. The rating for the navigation skill level is subjective in that it asks respondents to rate their own skill level on the scale from 1 to 5, with 1 being poor and 5 being excellent.

The survey's second section solicited two route descriptions from respondents. The instructions first asked respondents to describe an outdoor route which could be used to guide a fellow traveler from the entrance of one building to the entrance of another building. Respondents were then asked to describe an indoor route which could be used to guide a fellow traveler from one room in a building to another room in the same building. In both cases, the instructions required that respondents describe real-world routes with which they were familiar. Respondents were also instructed to write the route descriptions as if they were describing the route to a fellow traveler with the same visual impairments and the same traveling experience and skills. For example, respondents who used a guide dog were asked to write their route descriptions so that another guide dog handler would be able to follow the directions. When writing the route descriptions, respondents were asked to assume that the other traveler had no current knowledge of the route they were describing.

As of this writing, we have received 35 responses for a total of 70 route descriptions (35 indoor and 35 outdoor). The demographics of respondents are summarized in Table 1. Seven respondents reported having another impairment which affected their navigation skills. Three respondents reported having hearing problems, one reported hypopituitarism (a disease of the pituitary gland causing symptoms such as fatigue and muscle weakness), one reported problems crossing streets due to post-traumatic stress disorder after an auto-pedestrian accident, one reported an inner ear balance disorder that affects mobility and travel skills, and one reported mobility and gait problems.

Field	**Response**	**Number of Responses**
Gender	female	18
	male	17
Age (in years)	$age < 20$	1
	$20 <= age < 30$	7
	$30 <= age < 40$	6
	$40 <= age < 50$	4
	$50 <= age < 60$	13
	$60 <= age < 70$	3
	$70 <= age < 80$	1
Highest education level	high school	3
	some college	6
	two-year college	3
	undergraduate degree	8
	graduate degree	15
Level of blindness	complete	18
	low-level	17
Number of years navigation impacted by vision loss	$years < 10$	3
	$10 <= years < 20$	4
	$20 <= years < 30$	9
	$30 <= years < 40$	8
	$40 <= years < 50$	4
	$50 <= years < 60$	6
	$60 <= years < 70$	1
Navigation skill level	fair	4
	good	5
	very good	17
	excellent	9
Navigation aid	cane	28
	guide dog	6
	other	1
Received O&M training	yes	30
	no	5
Has other impairment affecting navigation	yes	7
	no	28

Table 1: Respondent demographics

Route Ontology

Our ontological analysis of verbal route descriptions is rooted in the ontological framework first developed by Lynch (Lynch 1960) and subsequently elaborated by Wunderlich and Reinelt (Wunderlich & Reinelt 1982), Presson and Montello (Presson & Montello 1988), and Allen (Allen 1997; 2000).

Route descriptions are segmented into environmental features, delimiters, verbs of movement, and state-of-being verbs. Environmental features are nominals that refer to objects or attributes thereof that are perceptible to the navigator. For example, landmarks, pathways and choice points are environmental features. Landmarks are environmental features that can function as points of reference. Hill and Ponder (Hill & Ponder 1976) define landmarks as any familiar object, sound, odor, temperature, tactile, or visual clue that is easily recognized, constant, and has a discrete permanent location in the environment known to the navigator. Pathways are nominals referring to channels of movement, e.g., streets or hallways. Choice points are points en route where directional decisions are made, e.g., intersections.

Delimiters are statements that provide discriminative information about environmental features (Allen 1997). Delimiters are subdivided into direction and distance designations. Distance designations are statements that separate environmental features in terms of standard units (e.g., meters), conventional units (e.g., city blocks), and deictic units (e.g., nearby). Direction designations describe spatial relations among environmental features in terms of the allocentric (object-to-object) and egocentric (self-to-object) frames of reference. For example, *north of the Main Street* is an allocentric direction, whereas *to your left* is an egocentric direction. Direction designations include such prepositions and prepositional phrases as *to*, *toward*, *away from*, *behind of*, *in front of*, *beside*, *between*, and *across* (Talmy 1983).

Verbs of movement denote mobility and orientation directives. In the case of sighted travelers, verbs of movement are partitioned into two broad semantic categories: *go* and *turn* (Allen 1997). In the case of visually impaired travelers, it is reasonable to expect verbs of movement to include references to O&M skills. For example, *touch-and-slide* to locate the curb refers to one of the four basic cane sensing techniques (*two-point-touch*, *three-point-touch*, *touch-and-drag*, and *touch-and-slide*) taught during the O&M training. *Shorelining* is another O&M technique whereby the navigator three-point-touches with her cane to keep track of a pathway.

State-of-being verbs describe relations among environmental features en route (e.g., *the bakery is north of the library*) or perceptual experiences (e.g., *you will sense an opening on your right*). We expect that the category of state-of-being verbs to include many references to perception through sound, touch, and smell, because visually impaired navigators rely on these sensory inputs to determine environmental features.

Route Analysis

Our route analysis is in its early stages. Currently, the analysis consists of analyzing each individual sentence in each route description and classifying various components according to the modified ontology described below. As of this writing, 20 of the 35 indoor routes have been manually analyzed and classified. No outdoor route descriptions yet have been analyzed.

In our initial analysis, the four components of the original analysis (environmental features, delimiters, verbs of movement, and state-of-being verbs) appeared to be too generic. To add specificity, we included sub-categories to three of the components: environment features, delimiters, and state-of-being verbs. The verbs-of-movement category does not appear to require a finer level of detail. The basic structure of the ontology is as follows.

- Environmental features: sense, sight, smell, sound, taste, touch, named
- Delimiters: distance, sequential, spatial, countable, descriptive
- Verbs of movement
- State-of-being verbs: exocentric, egocentric

Environmental Features

Since visually impaired travelers experience the world differently than sighted travelers, we thought it may be informative to see if the objects in the route descriptions fall into different groups. We have identified seven categories of features: sense, sight, smell, sound, taste, touch, and named. Sight, smell, sound, taste, and touch are objects that a person references in relation to a specific sense. For example, in the sentence *You may smell the food cooking*, food would be considered an environmental feature related to the smell category. Sight is included since we thought that some participants with low vision may possibly reference limited vision information. The sense sub-category is for phrases such as *You will sense an open area to your left*. In this case, one of the specific five senses is not named, but there is a given “feeling” that an object or area is nearby. The named environmental feature is a catch-all for any object which does not fit into one of the other environmental feature categories.

Of the seven environmental categories, the unclassified named category is used the most, 135 unique objects have been classified as named. The six most mentioned objects are doors (present in 13 of the 20 analyzed descriptions), walls (11 descriptions), entrances (9 descriptions), offices (8 descriptions), and hallways and elevators (both in 7 descriptions).

The next largest sub-category for objects is touch (31 objects). The three objects most referenced in this category were walls (5 descriptions), buttons (4 descriptions), and railings (3 descriptions). Another object classified as touch is the cane with which the user walks. This object is unique because it could be considered part of the traveler, but it is still being referenced in the route description. An example of cane usage in a description is *When your cane hits the wall, turn right*.

The third largest category was sound (28 objects). Examples of objects in this category are water fountains (2 descriptions), echoes (2 descriptions), and doors (2 descriptions). Note that doors are sometimes described as a sound feature and sometimes as a named feature. In most cases, the descriptions reference a door without any special qualifier, but there are references to doors, as in *Walk until you hear the first door and enter*, that uniquely identify the sense used by the traveler.

We have not yet found many uses of the remaining categories. The sense category had two objects: doorway (1 description) and wall (1 description). The smell category is only referenced with one object: food. No examples of objects in the sight and taste categories have been found yet.

Delimiters

We have identified the following categories of delimiters: distance, sequential, spatial, countable, and descriptive. A distance delimiter is any word or phrase that refers to moving some length. A sequential delimiter is one that limits the relation of one object to another. For example, in *the water fountain is after the door*, the phrase *after the door* is considered a sequential delimiter. A spatial delimiter is a sort of spatial information that covers directions. A countable delimiter is any delimiter which gives a specific count of an object, e.g. *walk past two doors*. Finally, the descriptive delimiters are used for any word or phrase which describes an object. For example, *in the steel door frame is to the right*, the word *steel* would be considered a descriptive delimiter since it describes the door frame.

The spatial category is the most used delimiter with 184 unique phrases classified. The three most used single word spatial delimiters are left (20 descriptions), right (19 descriptions), and straight (13 descriptions). All four compass directions are used as well - north, south, east (4 directions each) and west (3 directions). Other spatial delimiter include such directives as *through the door*, *along that wall*, and *across from the door*.

The descriptive category is the second most used category with 132 unique phrases. Unlike the objects, no one description appears to be favored over the others. We may need to divide this category into other finer-grained sub-categories. One possible sub-category may be texture. Example of textures include references to floors - carpeted, tiled, stone, bumpy, rough - and door materials - wood, glass, and steel.

The sequential category with 54 unique phrases includes phrases such as *before you enter the steel door frames*, *from carpet to stone*, and *past them there is a large room*. As with the descriptive category, no single set of phrases stands out. The countable category, with 27 unique phrases, tends to reference specific objects. Typically, it is used to count either the number of doors, floors, or objects in an area that need to be passed.

The distance category, although the least used category with 22 unique phrases, is proving to be informative. There are two basic sets of distance measurements used in the analyzed route descriptions: the number of steps to take and the distance in feet or meters to walk. It appears that steps are given as a measurement when the distance is very short and counting is easy - 2, 3, and 6 steps in the routes analyzed so far. There appears to be a point in the distance where people switch over to using feet and meters. The shortest distance mentioned is 5 feet and the longest distance is 100 feet. In all cases, for both steps and feet/meters, the distance is prefixed with the qualifiers *about* or *perhaps*. This may reflect the understanding for step-type distances that not everyone's stride length is the same and for feet/meter-type distances that it can be difficult to accurately judge the distance.

Verbs of Movement

The three most used verbs of movement are *turn* (16 descriptions), *walk* (14 descriptions), and *go* (9 descriptions). While these verbs are used by sighted people as well, some descriptions contain verbs that are distinctly related to how the visually impaired travel and observe their environment. When a visually impaired person walks down a hall using a cane, they cannot usually detect obstacles beyond the end of their cane. Obstacles and protrusions, such as water fountains, if not making a sound, are often only detected when contact is made with either the cane or the traveler's body.

The verbs *shoreline* (1 description) and *trail* (2 descriptions) are two commands which reflect a distinct action or method of travel that blind people may need to perform that sighted travelers do not. Shorelining, or trailing, is the act of following the connecting edge of two objects. An example of shorelining indoors is using a cane to follow where a floor and wall meet; outdoors, following where the edge of a sidewalk and the grass meet. This helps keep the individual traveling in a straight line or following the path of a particular object. Another example specific to a blind traveler is the verb *ask*, as in *ask your dog to find the elevators on the left*. Given the context of this statement, *ask* is classified as a verb of movement. Again, this would be specific to a blind user who travels with a guide dog. All three examples here - *shoreline*, *trail*, and *ask* - can be reduced to *go*, but they reflect a *go* that is specific to individuals with visually impairments.

State-of-being verbs

Allen defines state-of-being verbs as "verbs which are reducible to is." (Allen 1997; 2000). The analyzed route descriptions reflect this definition in that the verb be is used in 17 descriptions. However, to reflect the fact that the visually impaired often experience the world through senses other than sight, we have created two sub-categories, exocentric and egocentric, to see if the route descriptions favored one type of statement over another. State-of-being verbs classified as exocentric are verbs that describe two more objects without reference to the traveler. For example, in the phrase *the door is to the right of the water fountain*, no reference is made the traveler so the verb *be* in this phrase would be classified as exocentric. State-of-being verbs classified as egocentric describe the environment in terms of the traveler. For example, the phrase *the door is to your right* describes where the door is in relation to the traveler's position, so in this case the verb *be* is classified as egocentric.

When the state-of-being verbs component is divided into the two categories, the number of unique egocentric verbs is almost twice the number of exocentric verbs, 44 egocentric versus 21 exocentric. The verb *be* is still the most used verb in both categories, 15 descriptions use it in an egocentric form and 13 in an exocentric form, but describing the environment in terms of the traveler appears to be more important than describing the environment in terms of itself. The wider variety of verbs in the egocentric sub-category reflects this. This preference for egocentric descriptions can possibly be explained by the limited range the visually impaired have for sensing the structure and state of the environment around them.

Conclusions

If routes are well described for a given environment and collections of route descriptions are made available, then the visual impaired will have a powerful tool. University students new to a campus could independently find their classrooms.

Travelers to cities could explore tourist sites in a manner similar to sighted visitors. The accessibility barriers for visually impaired navigators would be drastically lowered.

A well-formed ontology for route descriptions to the blind will serve multiple purposes. Using the ontology as a guide, sighted people could be enlisted to initially build and tag basic collections of routes. Later, using collaborative tools, the visually impaired could refine the routes, add new tags and routes, and manage the emerging route collections. The ontology could also serve to help define a structure that would ensure that software tools could be developed to extract and develop new routes from the user-provided data. In time, one can envision databases of route descriptions accessible through multiple devices such as desktop computer systems, PDAs, cell phones, and electronic travel aids. Such databases would likely be relevant to people with cognitive disabilities, allowing them to travel independently in their environment as well.

We are working toward a collaborative online service that can be managed by individuals with visual impairments independently or as an enhancement to other navigation technologies. Many navigation technologies use GPS to guide travelers around outdoor environments, but GPS does not work indoors. Our service could eventually be used in conjunction with GPS and other existing outdoor-oriented travel aids to guide an traveler through both indoor and outdoor environments with comfort and ease.

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