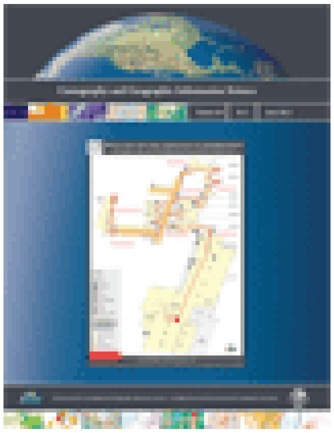

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One of the most scrutinized contemporary techniques for geospatial data collection and production is crowdsourcing. This inverts the traditional top-down geospatial data production and distribution methods by emphasizing on the participation of the end user or community. The technique has been shown to be particularly useful in the domain of accessibility mapping, where it can augment traditional mapping methods and systems by providing information about transitory obstacles in the built environment. This research paper presents details of techniques and applications of crowdsourcing and related methods for improving the presence of transitory obstacles in accessibility mapping systems. The obstacles are very difficult to incorporate with any other traditional mapping workflow, since they typically appear in an unplanned manner and disappear just as quickly. Nevertheless, these obstacles present a major impediment to navigating an unfamiliar environment. Fortunately, these obstacles can be reported, defined, and captured through a variety of crowdsourcing techniques, including gazetteer-based geoparsing and active social media harvesting, and then referenced in a crowdsourced mapping system. These techniques are presented, along with context from research in tactile cartography and geo-enabled accessibility systems.

Keywords: crowdsourcing; accessibility; blindness

Introduction

Humans gather information about their world through multiple sensory channels, including vision, touch, and audition, and share this information to increase understanding of the world. Symbolic methods for encoding and communicating, such as writing, are used to share information, extending the immediately observable world into the unknown. Robinson and Petchenik describe maps as being similar to writing; in that, they are useful for graphically expressing mental concepts and images (1976, 1).

Cartographers have, over several millennia, refined methods and techniques for graphically encoding and communicating spatial information, and these techniques are being studied extensively with regard to form and function. With only a few exceptions, these cartographic methods and techniques rely on vision as the exclusive domain for sensory interaction.

Clearly, vision is the most important sense for cartography; yet, many individuals lack the visual acuity that is so important for creating, using, and understanding traditional maps. As an alternative for people with serious visual impairments or total visual disability, several cartographers have developed methods for augmenting and even replacing visually presented information with simplified and generalized information presented in other sensory domains. A general approach is based on the development of a geospatial database that defines the locations and characteristics of geographic features. This database is then used to create an effective nonvisual presentation of information in the cartographic domain.

We present a contemporary approach to geospatial data collection and data capture using crowdsourcing to report, locate, and define transitory obstacles in a built environment. These transitory obstacles represent a significant hazard for nonvisually navigating known and unknown spaces, and while the focus of this research article is on mapping and accessibility issues related for blind and partially sighted people, the benefits of this research effort will be shared by other types of disabled people, including those with mobility impairments.

Efforts to quickly report, geolocate, and define transitory obstacles would present a major advance in cartographic support for blind and partially sighted people. The contemporary techniques described in this paper include gazetteer-based geoparsing, active harvesting of navigational points of interest, and ambient geographic information (AGI) present in social media. These techniques

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contribute to the characterization of transitory obstacles and facilitate their display in a crowdsourced accessibility system. A timeline of techniques are presented as a logical progression from developments in tactile cartography, automation of tactile map production, and previous geo-enabled accessibility systems.

Tactile maps and accessibility systems

Tactile maps and graphics (Figure 1) have been used for decades by blind and partially sighted people and form a starting point for most discussions related to accessibility systems. This research paper does not deal explicitly with the cognitive aspects (which are reviewed comprehensively by Montello 2002) or specific map design and usability guidelines (Perkins 2002; Tatham 1991; Rice et al. 2005; Golledge, Rice, and Jacobson 2005; Lobben 2005). However, a discussion of tactile maps, production methods, and general development is a useful basis for exploring the reasons for approaching accessibility systems using crowdsourcing for identifying navigation obstacles and hazards.

Tactile maps

In the United States, for many decades, primary schools have been supplied with an assortment of vacuum-formed tactile maps showing topographic relief and globes with simple tactile topographic representation. They are familiar methods for representing topographic relief to children, and at the same time, represent a very small and arguably obscure corner of the cartographic universe. Tactile mapping is described by Perkins as a “specialist field … often perceived as marginal to more mainstream cartography” (2002, 521).

Within the discipline of geography, the use of tactile maps and graphics has a long history (Wiedel 1983; Tatham and Dodds 1988). In his comprehensive review of progress in tactile mapping, Perkins cites significant research efforts dating back at least to the 1970s (2002, 523) and comprehensively reviews tactile map research in the areas of cognition, design, standardization, production, technology, and ethics.

Figure 1. User interacting with tactile map.

Early efforts in tactile symbolization include those by Jansson (1972), who explored the discriminability and usefulness of symbolic patterns. In 1991, Tatham reviewed tactile map design principles, presenting symbolization suggestions for points, lines, and areas based on experimentation and theoretical considerations. Standardization criteria were suggested based upon discrete, static measurements for cartographic representations (e.g. point symbols should be between 2 mm and 10 mm in size). In contrast, Eriksson (2001) argues against general width, height, and surface patterns, suggesting that tactile map symbolization guidelines and parameters are a function of scale, level of detail, and the amount of simplification required. These tactile symbolization suggestions and guidelines have been used to develop tactile maps for mobility, which are critical in helping blind and partially sighted people navigate through the built environment (Golledge, Rice, and Jacobson 2005).

A recent research emphasis has been placed on developing maps that use haptic feedback, which involves tactile feedback through the skin as well as active feedback through the muscular and skeletal systems in response to a force. Haptic feedback is usually delivered through a computer device with servomechanisms, actuators, or electromagnetics, as discussed in the context of basic shape identification and cartographic presentation (Rice et al. 2005). Two primary properties of haptic sensing that are relevant for creating haptic maps and graphics include the geometric and material properties of objects (Klatzky and Lederman 1993). Rice et al. (2005) explore some preliminary cartographic design guidelines for haptic maps, while Griffin (2001) presents an exploratory use of haptic feedback within a geovisualization setting. Golledge, Rice, and Jacobson (2005) present a comprehensive overview on the use of haptic maps and graphics. In collaboration with blind sailors, Simonnet et al. (2009, 2010, 2011) developed a virtual haptic environment for nonvisual trip planning and onboard navigation.

These previous research findings strongly suggest that the presentation of spatial information through nonvisual means is a viable source of information sharing. However, the production of that information has historically presented difficult challenges for traditional cartographers.

Tactile map production cycles and geotechnology

Production techniques, technologies, and large-scale production projects can be problematic for tactile maps. Taylor (2001) summarizes on the many technical and administrative challenges in the large international tactile atlas project for Latin America. Przyszewska et al. (2011) discuss the significant design work required for a professionally-produced series of tactile maps for Poland. Production technologies are discussed by Perkins (2001), including a useful comparison of two common tactile map production methods (vacuum forming or thermoforming and microcapsule paper), noting the relative advantages and disadvantages of each. In his later 2002 review, Perkins notes the significant time required for the creation of the master molds used in thermoform maps.

Recognizing the difficulties posed by tactile map production techniques and in many cases, the significant time required for production, other authors suggest producing tactile graphics with geographic information systems (GIS) (Coulsen, Riger, and Wheate 1991; Miele et al. 2004) and scalable vector graphics (Gardner et al. 2001; Miele et al. 2005). As a framework for their work, many of these authors repeat an observation made first by Coulsen, Riger, and Wheate (1991) that GIS can be used to automate and accelerate the tactile map production process. Coulsen, Riger, and Wheate (1991) note that the great investment in GIS functionality to generalize and simplify features could be used to automate the time-consuming and tedious tactile map production processes, including the customization of symbols at a variety of scales. Coulsen, Riger, and Wheate (1991) arguments provide a framework to view our research approach. An important implication in Coulsen, Riger, and Wheate (1991) is that GIS can be used to more easily and quickly produce tactile maps, which is important in reducing the time required for a map production cycle. A shorter tactile map production process could lead to the capture of temporally transient obstacles that are important in navigation and wayfinding.

Perkin's 2002 review of technology as a fix for tactile map production includes an important discussion of ethics, noting the dangers of technocratic and positivist approaches that ignore the wider social constructions of visual impairment (2002, 525). There are a multitude of projects that harness GIS and geotechnology to produce maps for the blind and visually impaired; these projects need to include wider considerations of the social needs of their intended audience.

Accessibility systems

The lack of simplified map data and the general difficulty in mass producing tactile maps has led many research projects toward software-based spatial applications, GIS, and other geotechnology. Miele et al. (2004, 2005) present an approach for automated tactile map design using GIS street centerline files and a Braille embosser, a central component of Miele's Tactile Map Automated Production project at the Smith-Kettlewell Eye Research Institute (2011). Miele extends this approach with scalable vector graphics (2007).

A notable accessibility project is the University of California Santa Barbara (UCSB) Personal Guidance System (PGS; Figure 2). The project developed from a concept paper in 1985[1] to a mature system with a number of significant design and usability features, including GPS tracking, a functional GIS with pedestrian network data, and auditory orientation cues. The user interface was further refined with a vibro-tactile haptic pointer interface (Golledge et al. 1998; Loomis, Golledge, and Klatzky 2001; Golledge et al. 2007), which allows a user to receive additional cues about objects to which he or she is pointing. The UCSB PGS was heavily tested in real navigation settings (Marston et al. 2006, 2007) and involved approximately two decades of development, testing, and refinement. In the context of suggestions by Perkins (2002, 525) and many others, this project is significant because it was widely developed with direct input from blind individuals, and the system was shaped through an enormous volume of research on wayfinding, navigation, route selection, auditory perception, and practical usability by blind and visually impaired persons.[2]

A major drawback of the UCSB PGS and other similar systems is that they are closed with respect to map data and suffer from the same delays associated with the more conventional cartography. The system's base data has to be generalized and simplified, updated, added to existing data, and loaded into the system. There is no manageable way to include obstacles or events that are spatially and temporally variable and by their very nature cannot be captured in advance.

Recognizing the need for real-time accessibility information about obstacles and navigation barriers to supplement existing accessibility systems, Nuernberger (2008) presents methods for delivering information about environmental changes and obstacles to mobility-impaired people through cell phones. Barbeau et al. (2010) similarly demonstrate the effectiveness of a travel assistance device based on GPS-enabled smart phones used by disabled individuals riding public transportation. Both research projects demonstrate the feasibility of delivering real-time information about navigation events and obstacles to end users, representing a significant improvement from past paradigms associated with tactile maps and accessibility systems with fixed base data. Although Nuernberger (2008) and Barbeau et al. (2010) focused on general mobility enhancements rather than tactile mapping and visual impairment, the work is significant in demonstrating that accessibility systems can be augmented with real-time information.

Rice et al. (2012) present a preliminary research regarding – and a design for – an accessibility system that uses crowdsourcing to identify, locate, and characterize obstacles in real time. This research paper builds on

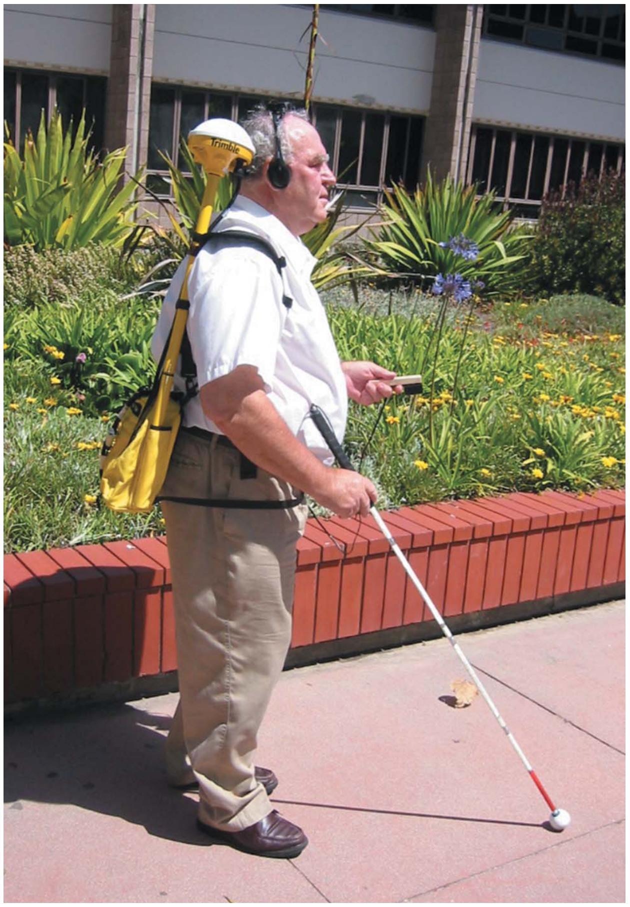

Figure 2. Dr. Reginald Golledge using the UCSB PGS, circa 2003.

this research, presenting several system components associated with geoparsing and gazetteer-based georeferencing, active harvesting from social media, and the use of crowdsourcing for data collection, validation, and community building. The accessibility system under development described in this paper and the individuals involved are aware and frequently reminded of the faults associated with technology-driven projects that are removed from the social context of blind, partially sighted, and partially mobile individuals. An important component of our work is community building, social dynamics, and awareness raised through the crowdsourcing activities, which are characteristics and benefits of crowdsourcing and public-participation approaches (Elwood 2010).

Crowdsourcing and social media techniques for accessibility

As noted by Golledge (2001) and echoed by Rice et al. (2012), a common problem for blind, partially sighted, and partially mobile people are obstacles in the built environment. The obstacles are frequently permanent features that hinder accessibility (e.g. curbs, barricades, and sloped walkways), but can be learned and avoided with time and effort. Similar static and semi-permanent features can be mapped using standard geospatial data collection techniques. A much more difficult category of obstacles are transitory barriers and hazards, which appear without notice and simply cannot be captured using standard techniques. These obstacles can be physical barriers placed temporarily across navigation pathways, areas closed temporarily for construction, or even large crowds or gatherings that are difficult to navigate through.

Accessibility systems that used tactile maps and other systems such as the PGS that use extensive GIS base data are unable to capture and display information about transitory obstacles and hazards. The goal of this research is to use a variety of social media and crowdsourcing techniques to identify, report, characterize, georeference, and communicate information about these transitory obstacles and hazards and present these obstacles and hazards to blind, partially sighted, and partially mobile users. We discuss techniques and approaches used in our research, including crowdsourcing and volunteered geographic information (VGI), harvesting ambient geographic information (AGI) from geosocial networks, extraction of points of interest and related navigation information, georeferencing, and local gazetteer development, followed by a description of the research and system design.

Volunteered geographic information and crowdsourcing

A great deal of recent attention has been focused on crowdsourcing and its use as a technique within geographic data collection and synthesis activities. It has been a significant element of projects that was completed under extreme time demands, due to the flexibility of the methods involved (Zook et al. 2010). Popular treatments of the subject (Howe 2008) and domain-specific treatments on crowdsourcing and related social media techniques (Goodchild 2007; Elwood, Goodchild, and Sui 2012; Sui, Elwood, and Goodchild 2013; Stefanidis, Crooks, and Radzikowski 2013; Zook et al. 2010; Ruitton-Allinieu 2011; Helbich et al. 2013) reflect the intense interest and attention the subject is receiving. The use of crowdsourcing in mapping for emergency response and disaster relief is a particularly prominent thread (Goodchild et al. 2010; Zook et al. 2010). Notable projects using crowdsourcing for geospatial data generation and compilation include OpenStreetMap, where end users have generated large geospatial data sets using crowdsourcing techniques (Haklay et al. 2008). These crowdsourced data sets compare favorably with government generated data sets with regard to accuracy (Haklay 2010), though coverage is less spatially uniform.

Arguments supporting the use of geospatial crowdsourcing include the benefits of local geographic expertise (Goodchild 2007, 2009), reduced costs for data collection and maintenance, temporal relevancy, and social and community engagement (Elwood 2010). These social and community benefits echo earlier work on public participation within the GIScience community (Obermeyer 1998; Sieber 2001). Perkins' encouragement of real-world applications for technical mobility research and the direct involvement of end users (2002, 524–526) supports our suggestion that crowdsourcing may serve as a complementary technique within an assistive geotechnology project, due to the focus on community, end users, and real-world application.

We next review two areas of current research that involve social media and crowdsourcing and describe how they contribute to our assistive geotechnology project. These areas include active harvesting of social media feeds for relevant geographic information and automated extraction of points of interest features and navigation data for accessibility.

Harvesting ambient geographic information from geosocial networks

In a recent paper, Stefanidis, Crooks, and Radzikowski (2013) introduce the concept of AGI and geosocial analysis, extending Goodchild's 2007 concept of VGI to include geospatial information harvested from social media feeds, such as Twitter. The use of AGI reflects an extension of the common metaphor found in early VGI papers of a large distributed sensor network, referring in this case to large human volunteer and end user communities which gather and disseminate information.

Among the various social media platforms, Twitter, due to its nature, appears to be the one where news breaks faster, compared, for example, to Facebook or Flickr. In their work, Stefanidis, Crooks, and Radzikowski (2013) showcased information harvesting from Twitter coverage in a variety of world events, ranging from the 2011 Arab Spring events to the devastating earthquake and tsunami in Japan in March 2011. In one of the most comprehensive studies to date assessing the performance of Twitter as a sensor network, Crooks et al. (2013) showed how Twitter data can be analyzed to assess the impact area of an earthquake. When it comes to events related to human activity, Wayant et al. (2012) showed how Twitter traffic can be analyzed to identify the spatial extent and temporal variations of protests in an urban environment. This is an important extension as it showcases the ability to harvest activity information in a geographic scale that is sufficiently specific to support obstacle identification for navigation and wayfinding, as discussed in this paper.

These studies provide insight on the potential to harvest accessibility information from social media, but up to this point, this capability can be considered to be indirect, in the sense that the information that is harvested is not directly accessibility information, but accessibility information can be derived from it. Accordingly, extending a system like the GeoSocial Analysis Workbench (G-SAW) developed by Croitoru et al. (2012) to bridge the gap from harvesting ambient geospatial intelligence to deriving specific accessibility information is a promising opportunity that should be exploited.

Extracting points of interest for accessibility through geographic information retrieval

Similar in nature to the techniques associated with the G-SAW, this research represents a step forward in the development of routines for geographic information retrieval that can be used to identify navigational points of interest embedded in unstructured text, which includes web pages, text archives, emails, messaging systems, and news stories in the area served by the system. The geographic information retrieval methods under development employ indexing mechanisms to improve the quality of geographic information retrieval from unstructured documents (Jones et al. 2008). As shown in the contextual summaries from geographic information retrieval papers and related work (Stefanidis, Crooks, and Radzikowski 2013; Croitoru et al. 2012), there is a need for geographically-aware search technology that can index and retrieve web documents according to their geographical context (Vaid et al. 2005). Various methods for refining and improving geographic information retrieval are being developed and deployed in software such as MetaCarta (Rauch, Bukatin, and Baker 2003), which serves as an exemplar for geographic information retrieval functionality.

Points of interest features and toponyms represent physical locations or destinations at a finer scale than typical administrative or political boundaries and can be encoded and stored in a database with a point or polygon footprint similar to political, administrative, and geographic toponyms in a traditional gazetteer (Hill 2009). Points of interests extracted for this project begin with a search for generic references to features such as "café," "museum," "park," or "school." By capturing these common variables (indicative of a potential points of interest), a code-based read can be made within an electronic document to capture these local points of interests with minimum use of an authority data set. To ensure that only the points of interest's toponym is extracted, proper grammar and syntax can encapsulate the full name of the points of interest for storage. The means to extract local points of interests through common nouns and syntactical encapsulations can assist current geographic information retrieval applications in improving extraction of toponyms from social media and other streams of text. Another purpose in the current development of geographic information retrieval methodology is to create a comprehensive database of local points of interests and their locations to be used in refining the positioning of obstacles and descriptions of obstacle locations in the system. Verbal and written descriptions of geographic environments contain references to points of interest and their relation to other landmarks. Therefore, extracting the points of interest and storing them can be useful in augmenting base data for our system and in providing additional information to use in characterizing and georeferencing transient obstacles.

An accessibility system design: conceptual design

The conceptual design of the accessibility system is shown in Figure 3. Components of the system in green are associated with the primary data collection activities and the initial development work for this project. The display elements of the system in blue are under development using open source software and will include additional web-based haptic and auditory maps similar to those designed by the authors and reported in Rice et al. (2005) and Golledge, Rice, and Jacobson (2005). The location served by our system is the George Mason University (GMU) campus in Fairfax, Virginia, and the immediate surrounding neighborhoods, which feed pedestrian traffic onto the main campus.

As a starting point, the system development goals acknowledge that a successful crowdsourcing framework has some interplay between end users and authoritative elements. Goodchild (2009) describes hybrid systems, where authoritative content and crowdsourced content coexist. Goodchild clearly states that "hybrid solutions to the production of geographic data may well represent the best of both worlds" (2009, 95). The hybrid data and information for our system is shown in Figure 3 with three boxes in the upper left corner and is summarized

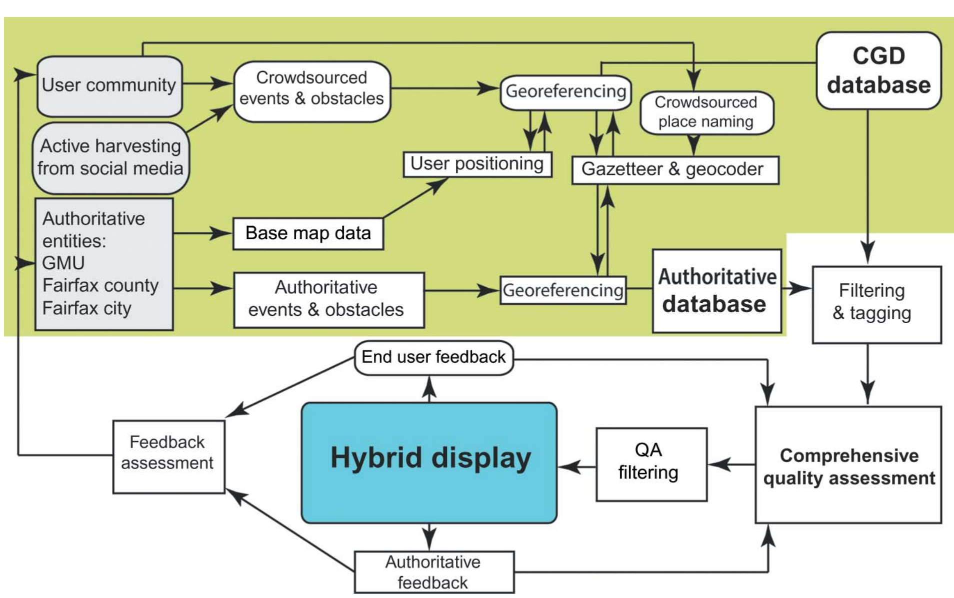

Figure 3. Conceptual design of GMU accessibility system.

as (1) information contributed directly by the user community, (2) information gathered by active harvesting of social media and the web, and (3) information contributed by authoritative sources, which in our context is the campus adminsitration, and city or county authorities for the surrounding jurisdictions. The system data consists of base map data, crowdsourced event and obstacle information, and authoritative event and obstacle information. The data is georeferenced using base data and gazetteer-based techniques (described below as well as in Rice et al. 2012) and stored in a database. After it is filtered, tagged, and quality assessed, obstacle and hazard information is displayed using a hybrid system that combines authoritative content with crowdsourced content and visually differentiates the two sources of data. For example, local construction activities that include barriers and fencing across walkways are mapped and stored by authoritative entities and are incorporated into our system. More transient obstacles, such as the temporary delivery of bulk construction materials onto a public right-of-way, are not mapped by authoritative entities because of their temporary nature. Through crowdsourcing, we gather information about these transient events and obstacles and combine these crowdsourced reports with the authoritative reports about obstacles and hazards. While this system operates, end user feedback is gathered along with feedback from campus, city, and county authorities.

Technical design considerations

For this research, several spatial and nonspatial web technologies are integrated and combined to form a system that captures and processes crowdsourced information and translates the information into spatial features. Our system includes several web applications for crowdsourcing, as well as applications for management. We are also developing mobile applications to provide display and alert functionality, including some support for nonvisual alerts. The web technologies utilized are HTML5, JavaScript, Leaflet, AJAX, JQuery, Google Maps API, PHP, and PostgreSQL// PostGIS. These web technologies are free to use and some are open source. In open source frameworks, GIS programmers are permitted to configure, use, and improve the software code for their specific needs. Open source provides an excellent approach with a flexible learning environment to understand how algorithms and various functionalities operate. Moreover, our system considers the benefit of the development total cost, which is significantly lower than with a proprietary approach, and allows us to focus resources on community building, outreach, and flexible software changes in response to end user input.

PostgreSQL is at the core of our system. It is a robust open source database management system. PostGIS is a spatial extension to PostgreSQL, which enables spatial functionality in SQL. The maturity and flexibility of this platform provide opportunities for integrating with web and other GIS software; for example, uDig, OpenGeo, OpenLayers, and GRASS. PostGIS can also operate on shape files, KML, GML, JSON, and its own binary data format.

The gazetteer developed for this research project, and described in Rice et al. (2012), is an important part of our georeferencing system and a useful component of validating positions supplied through user entry and through other metric georeferencing methods. Our gazetteer database has 26 fields containing comprehensive naming attributes of local geographic features (buildings, landmarks, sidewalks, parking lots, roadways, and monuments). The presence of a comprehensive naming system is essential in providing georeferencing for obstacles whose positions and characteristics are communicated by volunteers using simple unstructured text.

In our gazetteer database, we record each feature's official name, slang name, name without vowels (for matching misspelled place names), abbreviated name, and name in various common languages spoken by end users in the local area, which at present includes English, Spanish, Vietnamese, Korean, Mandarin, Arabic, and Urdu. When a crowdsourced item of interest is voluntarily contributed or extracted as a point of interest through geoparsing and geographic information retrieval, it is submitted to the system. The gazetteer database is searched to find any matched landmark name. A contains table is scanned to find any contained landmarks within the gazetteer database. An incident footprint is generated using PostGIS spatial functions and stored in a convexhulls table in both KML and binary formats. As a final processing step to enhance sorting and display of temporal relevance, four KML files are generated in the system with different temporal ranges that can be visualized through Google Maps API V3. The footprints contain the original crowdsourced message submitted by a user, displayed in a Google Maps API infoWindow. The success of our geographic information retrieval methods can be improved by refining geographic relationships, such as proximity and containment, to increase the precision of incident and obstacle locations and general points of interests and by developing appropriate measures of confidence, such as those describe by Larson (2011) and Andogah, Bouma, and Nerbonne (2012).

A supplemental component recently added to the system is a crowdsourcing tool allowing the users to contribute place names of any landmark in GMU's campus in languages spoken by the students, faculty, and staff. In the conceptual design diagram (Figure 3), this is noted as "Crowdsourced Place Naming." The user can select a language that will generate a Google Map designed specifically for the selected language. When the user clicks on a landmark, a Google's Map API infoWindow formatted using the JQuery library permits suggestions or corrections of official name, abbreviated name, or slang name. If

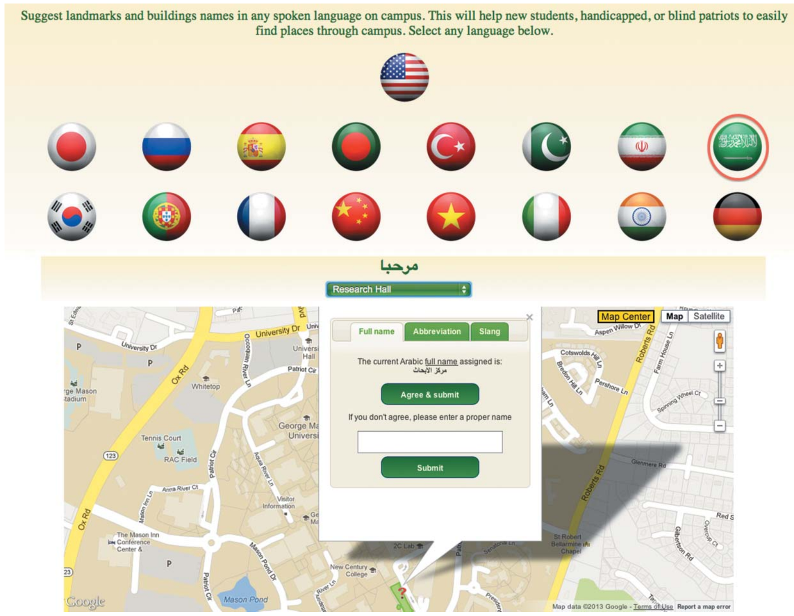

Figure 4. An end user contributes Arabic place names to a localized multilingual gazetteer used for georeferencing.

any of the names is not populated, the user can suggest a new name of any of the three name types mentioned above. Figure 4 shows the naming suggestion and correction approach in the system for a local landmark submitted in Arabic.

Existing development efforts have focused on simple crowdsourcing tools for identifying and georeferencing obstacles in the built environment and displaying those results along with authoritative base data and reports. Current efforts are underway to refine the reporting tools and the characterization of transitory obstacles, including pictures and examples of transitory obstacles used in training. A variety of quality assessment tools and feedback tools are also being developed to improve the system. Many of these tools are being refined with the input and direction of end users and the local community of blind, partially sighted, and partially mobile people.

Summary

The International Cartographic Association's Commission on Maps and Graphics for Blind and Partially Sighted People has been a significant outlet for research in the design and use of tactile maps and graphics. Many of these papers have focused on the symbolization, design, and production of tactile maps as a static cartographic product. More recent publications by Commission participants note an interest in using the technology to replace or augment traditional mapping methods such as tactile maps (Miele et al. 2004, 2005) and haptic virtual environments (Simonnet et al. 2009, 2010, 2011). Similar projects have had varying levels of success, as noted by Perkins (2002), due to an occasional over-focus on technical approaches at the expense of end users and real use scenarios. As a general advantage, the production methods discussed by Miele et al. (2004) and others are promising; in that, the underlying cartographic processes can be automated and could incorporate changing base data and transient obstacles.

A drawback of many accessibility systems is an inability to incorporate real-time information, though at least two projects (Nuernberger 2008; Barbeau et al. 2010) recognize this drawback and have integrated smart phone update elements into assistive geotechnology projects. The GMU Accessibility Project described here and in Rice et al. (2012) uses crowdsourcing and several secondary web-based and social media-based extraction and geographic information retrieval techniques to identify, geolocate, and characterize obstacles on a college campus where blind, partially sighted, and partially mobile students, staff, faculty, and visitors travel. The system described in this research paper is being developed and modified with end user feedback to achieve some of the important social considerations discussed by Perkins (2002).

Acknowledgments

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Notes

1. See http://www.geog.ucsb.edu/pgs/papers/loomis_1985.pdf, accessed November 1, 2012.
2. The UCSB PGS Project research team produced 42 peer-reviewed technical and basic research publications between 1985 and 2008 about system testing, design, and usability. See http://www.geog.ucsb.edu/pgs/publications.htm, accessed November 1, 2012.

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