ABSTRACT

Title of Document: SPECIALIZING PEDESTRIAN MAPS TO ADDRESS THE NEEDS OF PEOPLE USING WHEELCHAIRS: A CASE STUDY IN COMMUNITY-SUSTAINABLE INFORMATION SYSTEMS

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This study examined whether a community-sustainable information system could be competitive with a centrally-maintained system. We focused on a pedestrian navigation system designed specifically to address the needs of people using wheelchairs. To ascertain the need for such a system, we interviewed people who use wheelchairs on campus. After establishing the need for a new interactive map, we designed and commissioned the construction of TerpNav, an online navigation system that allows users to find a route that avoids certain obstacles, a feature specifically for people using wheelchairs. After TerpNav's release, we conducted surveys to determine user satisfaction. We found user maintainability was important to the system's responsiveness to change, which also affected user satisfaction. We then incorporated new community-sustainable features into a second TerpNav version. TerpNav's success demonstrates that community-sustainable information systems may be a viable alternative to centrally-maintained systems that are less easily specialized to serve individual community needs.

SPECIALIZING PEDESTRIAN MAPS TO ADDRESS THE NEEDS OF PEOPLE USING WHEELCHAIRS: A CASE STUDY IN COMMUNITY-SUSTAINABLE INFORMATION SYSTEMS

By

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(Finding Alternative Specialized Travel Routes)

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Chapter 1: Introduction

In 1990, the U.S. Congress passed the Americans with Disabilities Act to mandate the cessation of discrimination against people with disabilities and provide equal rights under the enforcement policies of the Fourteenth Amendment to the United States Constitution. In the ensuing years, the nation as a whole has become more conscious of the needs of people with disabilities, although there is still room for improvement. Even with wheelchair ramps, wheelchair-accessible bathrooms, and handicapped-accessible parking spaces, a major problem still persists: Information about wheelchair-accessible routes is hard to find and difficult to convey.

Traditionally, paper maps have served as the main means of displaying geographic and municipal information that could be used to find accessible route information. Paper maps, however, must be tailored to a specific data set, or they suffer from information overload and become too crowded. These maps are time intensive to produce and expensive to provide to people who generally only need information about a small area of the map. Any change to the environment might necessitate a brand new map, which is a problem when the environment changes often. Typically, map providers release maps intermittently and wait for major changes to occur before spending the capital to create and distribute new maps. As a consequence of these high costs combined with the relatively small consumer base, the needs of people with disabilities are often overlooked when creating paper maps.

With the advent of the computer, mapping technology in the form of geographic information systems (GISs) has accelerated since the 1980s (Jardine & Teodorescu, 2003). GIS-based maps are able to contain much more information because every piece of information does not need to be displayed at the same time; billions of bits of data can be linked to each other geospatially. New technologies allow map providers to lower the costs of drawing maps, although the costs of distributing maps were still high until the 1990s, when the mapping industry was transformed again with the rise of the Internet. GISs are no longer only available to institutions, universities, and large corporations; digital maps can now be enjoyed by the masses. Map providers have overcome the distribution problem by placing GISs on the Internet, enabling anyone anywhere with an Internet connection to access detailed navigation information, including driving directions to and from any area in the world.

Despite these advances in the mapping industry, maps still suffer from one key deficiency: maintaining the data's accuracy in real time. Just as with a paper map, any change to the environment necessitates change to the electronic map. Geographic information must be sustained, or kept accurate and current, in order for a map to continue being useful to its users. Because GIS technology available on the Internet is growing in both capability and popularity, these electronic maps are now dealing with large amounts of geographic information. Furthermore, larger areas require more effort to be sustained. Map providers generally place the responsibility of maintaining the data into the hands of a central authority, a group of people tasked with keeping the data as accurate and current as possible. Team Finding Alternative Specialized Travel Routes (FASTR) believes that this is an inefficient way to sustain geographic data.

The problem of sustainability can be related to the analogy of a community park and its maintenance staff. For the park's given size, a certain amount of maintenance and cleaning is required. If the size of the park increases, the amount of required maintenance and cleaning by the staff must also increase, not only because the area expands, but also because the number of people using the park increases. If additional staff is not hired, each maintenance staff member would have to individually maintain and clean more park area in the same amount of time. Again, this seems like an inefficient method to deal with the problem of increasing maintenance requirements.

What if, instead of hiring additional park maintenance staff, the park promoted a policy in which everyone who uses the park cleans up after him- or herself? Every park visitor would be asked to participate in keeping the park clean and usable. By asking everyone to participate in the maintenance of the park, the amount of cleaning required by the park maintenance staff might decrease.

Relating this analogy back to the issue of geographic information in maps, the same sustainability concept can be applied. Just as a community of park users can help maintain a park, a community of map users can help keep mapping data accurate and current. Incorporating user participation in a GIS allows a map to be sustained by its users. This concept of "community sustainability" is the main focus of our research study.

Today's world is dominated by individual curiosity; people want to know about everything that relates to them at all times, and modern technology feeds this curiosity. The rate at which the environment changes is increasing quicker than ever, and individuals' desire to know about change is increasing in the same manner. An example of the desire for up-to-date information is found in the abundance of traffic reports available today. Before the proliferation of electronic information sources, people relied on television or radio reports that only aired intermittently in order to know road and traffic conditions. Today, people can access websites from their personal computers or cell phones to see changes in their environment in real time. Before embarking on a trip, an individual can plan his or her route based on information regarding current traffic conditions, possibly making travel time more efficient. The responsiveness to change that real-time traffic reports exhibit is what people look for in all information systems today.

As of spring 2006, there were two maps of the College Park campus of the University of Maryland available for public use. There was an online "interactive" campus parking map provided by the University of Maryland Department of Transportation and a paper map of the campus distributed by the Visitor Center. Both maps included the same content and layout; in essence, they were the same map in different media. According to the University of Maryland Visitor Center, the Visitor Center map underwent minor updates once every academic year for at least the past 20 years, including the addition of newly constructed buildings and directory updates for any new or renamed buildings or departments.

Given the current desire for accurate, real-time information, a system that is updated yearly does not exhibit responsiveness to change. An environment can change at any time for a number of reasons: A building can be closed, a door can be broken, and/or other information can be outdated, and so on.

The University of Maryland College Park campus is primarily a pedestrian-based environment. The campus has a minimal number of roads, so that in general, the community relies on paths and sidewalks as the primary means of navigation. Relative to the amount of area covered by a typical online mapping application, such as Google Maps, the university campus is small. However, with hundreds of buildings and pathways, thousands of parking spots, and thousands of people interacting with the campus environment every day, the campus is always changing. A few administrators cannot possibly know every campus change in real time, meaning that the map cannot be reflective of the real-time conditions on campus. Team FASTR decided to focus our community-sustainability research on a pedestrian-based area with the potential for frequent change that employs a central authority to sustain its current map. The University of Maryland College Park campus provided a fitting environment for our community-sustainability research.

Changes to an environment affect different people in different ways and magnitudes. Revisiting the accessibility issues mentioned at the beginning of the introduction, people using wheelchairs are especially vulnerable to spontaneous changes to the environment. In addition, pedestrian paths are not as homogeneous as roads, meaning that people who use wheelchairs cannot traverse every path in the same way that they can travel on roads (Sobek & Miller, 2006). For example, temporary construction on a sidewalk hinders a person using a wheelchair more than a person walking because the person walking can step off of a path to avoid the obstruction. The person using a wheelchair, on the other hand, must backtrack his or her route and find a suitable, unobstructed path. However, if the person using a wheelchair had known about the obstructed path beforehand, he or she could save the time and effort necessary to backtrack. As mentioned earlier, information about accessible routes for people using wheelchairs is hard to find and difficult to convey, and the needs of people with disabilities are often overlooked when creating maps due to their high cost and relatively small user base. Team FASTR recognized this problem and focused its community-sustainability research toward this application: a navigation system for people who use wheelchairs in a pedestrian-based area.

Research Questions

In our study, we, Team FASTR, studied the broad subject of community sustainability. We focused our research on a population of people who are greatly affected by small changes to a pedestrian-based environment—people who use wheelchairs—choosing the University of Maryland College Park campus as our research area.

Team FASTR asked three questions to guide our research:

1. What do people using wheelchairs require from a community-sustainable navigation system?
2. How will we develop a community-sustainable navigation system that addresses the needs of people using wheelchairs?
3. What properties of the community-sustainable system will enable and attract participation by the community?

We recognized the need for an easy method for people using wheelchairs to access information regarding the navigation of a pedestrian-based area, but lacked knowledge on the specific information needed or desired by people using wheelchairs. We also needed to study general ideas on navigation systems and community sustainability to investigate the potential combination of these two ideas—a community-sustainable navigation system for a pedestrian-based area. Our first research question was addressed by a review of relevant literature, interviews of our target population, and a study of the maps of other college campuses. Through the literature review, we obtained information on general accessibility needs, the technology of navigation systems, and community sustainability, although we were not able to acquire specific, personalized data regarding the needs of people using wheelchairs in navigating a pedestrian-based area. Therefore, we decided to go directly to our primary user base and interview people using wheelchairs at the University of Maryland College Park campus in order to acquire this information. We also studied and analyzed the maps of other college campuses in order to learn what information is currently present in maps of pedestrian-based areas, specifically college campuses, and which implementation methods work best.

The second research question involved the actual development of a community-sustainable navigation system. With support from reviewed literature, we came up with a concept and general design of a navigation system. The technical development of the computer software was aided by the expertise of computer science students at the University of Maryland assembled in teams under the Software Engineering at Maryland (SEAM) project curriculum. This curriculum places the student teams in real-world scenarios where they must complete projects for a client, typically an actual company or organization outside of the Computer Science Department. Team FASTR was the client for several SEAM teams, and our proposed community-sustainable navigation system was the assigned project. The development process underwent two iterations—the first to develop the general proof-of-concept system, and the second to expand the system's features and capabilities in order to invite more community participation.

The final research question was another critical focus of our research. We recognized that the concept of community sustainability relies on community participation. In theory, increased participation leads to better results, or in this particular case, better accuracy and more current data information. Accordingly, we needed to research methods, properties, and features to implement in the community-sustainable navigation system that would attract the participation of the community. We used information gathered from a review of relevant literature, our interviews, and several original ideas to answer this question.

In order to evaluate our conclusions to the three research questions, we conducted survey research and a usage analysis after the first iteration of development. We invited the community of the University of Maryland College Park campus to use our proof-of-concept community-sustainable navigation system. After several weeks, people who had used the system were asked to complete a survey, providing us with feedback from the community. We also conducted a statistical analysis of the system's usage logs in order to determine how the system was used. We analyzed results from these evaluations and used this information to develop ideas for the second iteration of development, in which additional features and capabilities were added to attract further participation from the community.

Assumptions

Team FASTR made several assumptions in conducting this research study. Our first assumption was that the University of Maryland College Park campus would always be changing. Evaluating the history of the university, the amount of changes that team members observed while at the university, and future plans for the university, we believe that this is a safe assumption, but also one that needs to be stated outright due to its importance to the project's focus on community sustainability.

Team FASTR also assumed that some of the mobility concerns of people who use wheelchairs could also be applied to other groups of people. For example, a person using a wheelchair is generally concerned with finding paths that have ramps instead of stairs. A person on crutches, on a bicycle, or pushing a stroller could also have the same concern for his or her navigation. Although this is not true of every person who uses crutches, bicycles, or other items that affect navigation, we state this assumption to say that this research can be applied to people in those audiences as well. However, we maintain people using wheelchairs as our primary beneficiary audience.

Hypotheses

Team FASTR made the following hypotheses to test in this research study:

H1: People using wheelchairs have difficulty navigating the University of Maryland College Park campus.

H2: The University of Maryland College Park population has a need for a navigation system such as we have proposed.

H3: The population of people using wheelchairs has a need for a navigation system such as we have proposed.

H4: An interactive map is preferable to one that is not.

H5: A community-sustainable map is preferable to one that is not.

H6: General users will be satisfied with our campus navigation system and want to use it.

H7: People using wheelchairs will be satisfied with our campus navigation system and want to use it.

H8: Our community-sustainable map will be more reliable and up-to-date than a nonsustainable map through participation by the community.

H9: An area is best known by the people who spend time in it on a regular basis.

H10: People using a community-sustainable map want to participate and keep the map up-to-date.

Product of the Research—TerpNav

Our research produced an online community-sustainable navigation system for the University of Maryland College Park campus that we named "TerpNav" (found at www.map.umd.edu). In developing TerpNav, Team FASTR had three major implementation goals: interactivity, accessibility, and sustainability. Addressing our first goal, interactivity, we wanted to make a map that was both easy to use and useful for individuals navigating a pedestrian-based area; in this particular case, the College Park campus of the University of Maryland. Addressing our second goal, accessibility, we wanted the map to contain information and features that would address the needs of people using wheelchairs in a pedestrian-based area. Addressing our final goal, sustainability, we wanted to explore methods of increasing community participation in our navigation system in order to keep the map accurate and current, exhibiting responsiveness to change.

TerpNav has six major features: finding locations, finding events, finding routes, filtering routes, avoiding points, and reporting errors. TerpNav's "Find Locations" feature is capable of finding buildings, fields, and parking lots across the campus based on user searches. To find buildings, TerpNav recognizes building names, building numbers, and building codes. The "Find Events" feature provides the same functionality as "Find Locations," but instead of locating areas of the campus, this feature locates any campus events that are loaded in the TerpNav database. TerpNav's "Find Route" feature calculates a route and distances between any two points on the map using any paths that are loaded in its database. A user can either use the "Start/End Locations" tab to search for "Start" and "Destination" locations or custom select the "Start" and "Destination" locations by clicking on the map. TerpNav's software calculates the shortest route between these two locations. These three features contribute to the interactivity of TerpNav.

Addressing our goal of accessibility, Team FASTR implemented the use of route filters and the option to avoid points. Using the "Route Filter" feature, a user can select from three route filters: one that avoids stairs; one that avoids all routes without sloped curbs, or curb cuts, when crossing a road; and one that avoids steep inclines or declines. Selecting one or more of these route filters commands a recalculation of the route, allowing the customization of a route to the user's specifications. In addition, if a user already knows or decides that a certain area of the campus is not traversable, whether due to accessibility issues or temporary occurrences like construction on campus, the user can choose to have TerpNav automatically avoid any route that passes through that area by adding an “Avoid Point,” a box of customizable size that can be placed anywhere on the map. These two capabilities contribute to the accessibility of TerpNav.

The sixth feature of TerpNav, the “Report Error” feature, addresses the final goal of sustainability. If a user realizes at any time that there is something incorrect, out-of-date, or missing in the map’s data, he or she may report the error to an administrator. Administrators of TerpNav have access to two databases: (1) OpenStreetMap, an online community-sustainable GIS that is the source of all of TerpNav’s base geographic data, such as the locations of paths and buildings, and (2) the TerpNav database that contains all of TerpNav’s extra information, such as building information, campus events, and reported errors. The administrator can make changes to either of these databases based on the type of error reported. The “Report Error” feature encourages the community to actively participate in keeping the map sustained. In addition, using OpenStreetMap as the base map exhibits TerpNav’s responsiveness to change, as this GIS is sustained by the community and changes in real time. These features contribute to the sustainability of TerpNav.

The following chapters describe the details of Team FASTR’s community-sustainability research and its application toward a community-sustainable navigation system for a pedestrian-based area that addresses the needs of people using wheelchairs. To see the team’s achievements along the way, see Appendix A.

Chapter 2: Literature Review

Accessibility

Americans with Disabilities Act

In designing TerpNav, it was important to take into consideration the challenges that people using wheelchairs face, as this was our target population. One important breakthrough for people who use wheelchairs was the Americans with Disabilities Act of 1990 (ADA). The purpose of the Act was to give equal rights to all people with disabilities and to focus on discrimination in employment in state and local government services, places of public accommodation, and commercial facilities (U.S. Department of Justice, 1994). The most important ADA publication in terms of our research is the "ADA Standards for Accessible Design," which sets guidelines for the construction and improvement of all buildings to be properly accessible for people with disabilities (U.S. Department of Justice, 1994). Currently, every contractor is required by law to abide by the ADA guidelines when building a new facility. In addition, every establishment must abide by the minimum requirements set forth by the ADA or the establishment could be sued. The minimum requirements for accessibility apply to all new buildings and facilities, such as academic buildings and athletic facilities, as well as temporary structures. The only exemptions are buildings that are not "structurally practical," security observatories, and nonoccupiable spaces that can only be accessed by ladders, catwalks, and so on (U.S. Department of Justice, 1994).

However, the "ADA Standards for Accessible Design" guidelines only provide minimum requirements for accessibility; meaning, for example, that the guidelines dictate that at least one entrance to a building must be handicapped accessible, but it does not specify which one. Even if buildings abide by the ADA requirements, it is not always true that the accessible entrance is the same as the most commonly used front entrance. At the University of Maryland, where most of the buildings were built before the ADA was passed, the front entrance of buildings is not always accessible, and people using wheelchairs have to use a different door to enter the building.

In addition, although the ADA requires that there are a minimum number of accessible parking spaces per total amount of parking spaces, parking lots may be closer to a doorway that is not accessible, thereby making navigation to the accessible door more difficult (U.S. Department of Justice, 1994). Even with the appropriate accessible spaces available at the University of Maryland, not every building has a parking lot nearby as the university is a primarily pedestrian-based area, and people with wheelchairs may have to navigate even further to get to their desired destination. The ADA sets minimum accessibility requirements that have greatly increased the accessibility of buildings, although the ease of navigation to accessible structures remains an issue to people using wheelchairs.

The ADA does address accessible navigation pertaining to specific situations, such as construction. Construction sites must have a pathway that is accessible to people with a disability, although there is nothing in the ADA regarding the proper signage to show the accessible path (U.S. Department of Justice, 1994). Even though the ADA has greatly enhanced the accessibility of public spaces, better navigation information addressing the needs of people using wheelchairs is still needed, although we hope our research and TerpNav development will alleviate some of these difficulties.

General Accessibility Issues

As we stated, the ADA has improved accessibility standards for people who have mobility issues. However, people using wheelchairs still may face obstacles when traveling. An article in *The New York Times* profiled a woman who uses a wheelchair who had trouble getting into her local coffee shop. She stated, “Life in a wheelchair is a series of carefully calculated moves, and some of the obstacles are not merely inconvenient—they are also a violation of the federal Americans with Disabilities Act, enacted 18 years ago last month” (Charkes, 2008, p. WE6). The coffee shop was not violating the ADA and did have accommodations for people with disabilities, but even with these accommodations, people who use wheelchairs sometimes have a hard time navigating around areas. We are trying to improve these navigation issues with the development of TerpNav.

Another article from *The New York Times* described the thinking process of a woman who uses a wheelchair: “And her map, drawn in her memory, is divided into the easily accessible places and the more difficult ones, the ones she needs help to navigate” (Hershenson, 2003, p. 1). Individuals using wheelchairs must make extra effort to think about and plan where they want to go, keeping in mind that they are not able to navigate all of the places they would like to go by themselves. Our team hopes that by creating TerpNav, we are able to take the accessible map out of one’s head and put it in the computer. We hope to be able to help people by creating a map that acknowledges the fact that all routes and building entrances are not accessible to all people, and that provides specific information about the accessible routes and entrances to be used by people with mobility issues.

Current Accessibility Resources

The College Park campus of the University of Maryland has several accessibility resources already on campus, with Disability Support Service (DSS) being the primary resource for people with disabilities. DSS provides services such as testing accommodations, reading accommodations, deaf and hard of hearing services, and additional services to people with disabilities (University of Maryland Counseling Center, DSS, 2009). Students, staff, and faculty are able to go to DSS for support services; however, there is limited information concerning accessible navigation.

The President's Commission on Disability Issues (PCDI, 2007), which is composed of an array of faculty and staff members from all over the university, studies disability issues on campus while also trying to improve accessibility information on campus. The PCDI website includes information on facility improvements and future construction at the University of Maryland, as well as a webpage entitled "Campus Accessibility," which does not currently have any information (2007).

The University of Maryland Libraries (2009) website contains accessible parking and entrance information that is available for all of the major libraries on campus. This site has a list of the libraries on campus and the locations of accessible entrances, parking, restrooms, and other services in relation to the libraries, although it asks patrons to call in advance to obtain current information. Our team believes that with a community-sustainable navigation system, any information concerning accessible entrances or issues with navigation would be updated without requiring people with disabilities to take any extra effort before coming to campus. Instead of having dispersed accessibility information located in different areas of the University of Maryland website, our team wanted to create a navigation system that would contain all of this information in one easily found location.

All of the accessibility services offered by the University of Maryland are a great asset for people with disabilities, but they are not infallible. Reviewing the past and current problems faced by people using wheelchairs helped us to confirm that we wanted to help all disabled persons with navigating the campus, in addition to, or without, additional services.

Technology

To better understand all of the technical details involved in designing TerpNav, a review of past mapping technology research was essential. A review of background information allowed us to identify relevant achievements that have already been made in the realm of mapping technologies and to formulate realistic goals in the context of our project. In view of the planned framework of our mapping system, the integral processes can be summarized into four sections: geographic information systems (GISs), user interfaces, route calculation, and databases. There is an enormous amount of relevant research on the technical aspects of GISs , useful graphic user interfaces, efficient algorithms for route finding, and information databases. These sources informed our team on the groundbreaking research in mapping that has been done over the past few years to ensure that our research is both innovative and original. The review of technology literature aided the planning, creation, and implementation of TerpNav.

GISs

The first set of mapping technology literature sources we sought encompassed papers about GISs and the implementation of map services on databases. According to Wang, Yang, Yu, and Ren (2004), the traditional way that a map service runs involves several steps. A map server first receives requests from the user, where it constructs structured query language (SQL) statements requesting data and sends them to a spatial database. Then, the spatial database executes the SQL statements and sends the result back to the map server, where it is displayed for the user. Wang et al. proposed a method in which the map images are displayed for the user directly from the spatial database instead of being transmitted back to the map server. This method allows for a database to provide mapping service without having to use any map server. The method proposed by Wang et al. provides a process for tiles to be transmitted from the map server and displayed to the user. Although Wang et al.'s description of the traditional way that a map service functions was helpful, their proposed changes to this method were also interesting, as they speed up the information flow to the user.

Because TerpNav disseminates map information to the user on a computer, our navigation system can be classified as a GIS-based computerized information system. In addition to the basic GIS-based system proposed by Wang et al. (2004), there are other conceptual designs for such systems. Singh, Singh, Langan, and Kumar (2004) proposed an interactive computer information system based on an advanced traveler information system called a computerized visitor information system. The design of this system calls for a three-tier system that includes the presentation tier, the application tier, and the data tier. One of the major drawbacks in this system that the authors concede is that real-time information must be sampled at a rate low enough to minimize "communication overhead" and high enough to ensure the timeliness and validity of the data (Singh et al., 2004, p. 682). However, Singh et al. also noted that "maps and signs are not an interactive and user-friendly form of route guidance" (p. 679). As our literature review reveals, there is great potential for different types of information systems to serve as alternatives to paper maps.

In designing TerpNav, we knew that it would need to incorporate a large amount of data, including map tiles, route information, and building information. To minimize computational cost and thereby maximize the real-time user experience in developing a map, finding an efficient method of receiving queries, searching through data, and returning results is essential. Bandopadhyay, Ghosh, and Sarkar (2003) proposed a design for "distributed GIS" in which data is stored at multiple networked locations for faster computation and access. In this design, the queries from the user draw data from different sources distributed geographically. The system then processes and formats the data, overlays the data with a local data source, and generates information products to be returned to the user. Using this method, the authors hoped to "decrease the cost of geodata management and further increase the return on investment of geodata collection and establishment" (Bandopadhyay et al., 2003, p. 1,162). Distributed computing in this form could help maintain the performance of our system and its route calculations.

In addition to the research done on the structure of GISs and the methods for incorporating large amounts of data, there is also research on incorporating computer-aided design (CAD) drawings into GISs. As we began our research, we found that the University of Maryland Facilities Management Department already contained a wealth of mapping information on the University of Maryland College Park campus in the form of CAD drawings. However, with the rise of computer, graphic, and networking technology, digital maps have become increasingly more important. Chen and Liu (2005) proposed a method of generating high-precision road navigation maps from CAD geographic maps. Through experimentation, they demonstrated the efficiency and robustness of the proposed system. Their method can be used to convert existing map resources to data that can further the volume of information that is available to our map and the mapping community as a whole. Given that CAD maps of the campus already existed before we began our research, we considered using Chen and Liu's method to take advantage of the existing resources when deciding what to use as a base map for our navigation system.

Under the broad category of GIS, research has also been done on community-sustainable maps. Teranishi, Kamahara, and Shimojo (2005) proposed a map-based content-sharing system known as MapWiki, in which users can publish location-dependent information on a map as wiki contents. Wikis are webpages that require that their content by editable by almost anyone with a web browser and simple editing tools. Their purpose is to freely and quickly share information with large numbers of people. The authors define the MapWiki by its requirements and basic concept, and then describe the current implementation of the MapWiki. The basic concept of

MapWiki stems from the guidelines of wikis: Anyone can add, edit, or delete any content on the map; changes to the map are reflected immediately; and users are registered so that content sources and viewers can be identified. The concept presented by Teranishi and colleagues is very similar to our broad and overarching goal for TerpNav—community-sustainable mapping—and demonstrates that other researchers around the world are also thinking about this topic.

User Interface Design

The second set of sources we examined included research that has been done on the design of user interfaces. Along with the functionality and features of a computer program, its user interface is very important because it is what the user sees, interacts with, and gathers information from. The user's experience and satisfaction with the program may be hindered by an unintuitive or uninformative user interface. In a tutorial on user interface integration, Daniel et al. (2007) described the strengths and weaknesses of existing user interface frameworks and component technologies involved in presentation integration. The justification in presentation integration is that user interface development is one of the most time-consuming parts of software development, so finding ways to smoothly reuse components of existing user interfaces is of interest (Daniel et al., 2007). As a component of the development process, evaluating the effectiveness of user interfaces is time consuming in and of itself. Ivory and Hearst (2001) surveyed an extensive group of usability evaluation methods with an emphasis on the role of automation. They suggested ways to expand and improve existing usability evaluation methods (Ivory & Hearst, 2001). These studies on the effectiveness of user interface and methods to evaluate them indicated that the user's experience with the program is of comparable importance to the program's functionality itself. In designing TerpNav, we considered the fact that the user interface is a very important component of any computer program and can greatly affect the user's experience with the system.

Dijkstra's Algorithm

The third group of technology sources we sought pertained to the derivation of efficient and least time-consuming route-finding algorithms on maps. We found that one of the most well-known route-finding algorithms was Dijkstra's algorithm. This algorithm assumes that various locations on a map are represented as nodes and that routes are represented as connections between nodes (Noto & Sato, 2000). The first step of the algorithm is to mark the starting node. The second step is to calculate the cost of going from the starting node to any adjacent node. The node for which this cost is minimized is marked. The third step is to calculate the cost of going from the starting node to any node adjacent to the node marked in the second step. The node for which this cost is minimized is marked. Fourth, the second and third steps are repeated until the desired destination node is reached (Noto & Sato, 2000). In the context of TerpNav, "cost" is determined by the distance between nodes on the map so that each route calculation generates the shortest distance between the starting and stopping points.

Dijkstra's method is widely studied and is used in shortest path problems in computer science. Noto and Sato (2000) found an alternative way of finding a similar shortest route in a reduced time in an extension to the traditional Dijkstra's algorithm. This new method applies Dijkstra's algorithm twice, once beginning from the starting point and once from the ending point. This modification of the traditional convention reduces the number of nodes to be searched and restricts the search space. We thought that this method could be useful to TerpNav because one of the fundamental approaches in calculating the most efficient route is to "reduce the search space of the most commonly used short path routines (Dijkstra's algorithm)" (Wagner, Willhalm, & Zaroliagis, 2005, p. 1). Wagner et al. demonstrated that the search space of Dijkstra's algorithm can be reduced using several data manipulation techniques in an innovative method. They claimed that the new method is two times faster than computing the route from scratch. These two methods of reducing the search space of Dijkstra's algorithm have direct implications for the development of TerpNav, as they can increase the system's performance.

Liu and Tay (1995), opposing the supporters of Dijkstra's algorithm, developed a system called KB-RFinder, which combines a shortest path algorithm with knowledge about the road network for the more efficient computation of routes. They demonstrated that the Dijkstra algorithm is wasteful because it searches through the entire network for a solution. Humans, on the other hand, can isolate an area that contains the best solution using the process of heuristic search. Incorporating such problem-solving techniques into a computer algorithm would greatly reduce its computation time (Liu & Tay, 1995).

The sources on the computation time of Dijkstra's algorithm, both positive and negative, are important because a system's performance in calculating routes is dependent on the speed at which it can implement the algorithm. Minimizing the algorithm’s calculation time would not only save computational resources, but also provide a more enjoyable experience to the user of the routing feature.

Aside from Dijkstra’s algorithm for finding shortest routes, the user’s response to suggested route choices is also important to the mapping system’s success. Abdel-Aty and Abdalla (2006) collected and analyzed data on the access to and benefit from the use of advanced traveler information systems. They constructed five models based on route and mode choices, including the travelers’ mode choice, travelers’ diversion from the normal route, travelers’ compliance with pregenerated routes, travelers’ compliance with short-term traffic information choice, and multidimensional long-term route choices (Abdel-Aty & Abdalla, 2006). Among many key findings, the authors found that highly educated drivers and traffic information users were more likely to follow traffic information and route choices that were provided by the information system. They also found that as drivers became more familiar with the system, their compliance with traffic information and diversion from their habitual routes increased (Abdel-Aty & Abdalla, 2006). If applied to TerpNav, information regarding route preference could reveal how useful any information that is generated by our system is to users under various scenarios.

As Raubal and Winter (2002) pointed out, there are also limitations to the currently used navigation services and the presentation of routes. Raubal and Winter stated that such services often use route-finding algorithms that present users with sequences of instructions that are based solely on geometric data, which is often the only type available. Raubal and Winter assessed the value in enriching route-finding algorithms with local landmarks. They integrated landmarks into way-finding instructions in the city of Vienna, Austria as a demonstration of the usefulness of their method. Because TerpNav is based on an area in which buildings are static, implementing a landmark-based route-finding algorithm could prove useful if step-by-step directions are ever implemented in TerpNav.

Database Management

The fourth set of technology sources that were important to our project pertained to methods of database management. In our product, the backend server computer stores, processes, and generates the raw map data, geographic objects, and map features (e.g., filters, building information) in SQL databases. The amounts of data that are involved in these three groups make research on efficient database management important to TerpNav's development. Charlot (2002) suggested that an ideal database tool should contain a uniform user interface, a simple terminal-like interface, a means to browse the database data content, intelligent browsing capability, reverse engineering of database objects, support for expert knowledge, and a means to export and import database data content. He identified the problems that current database tool software has, including the existing incompatibility between different database vendors. He presented the layout of dbAnalyst, which he claimed to be the "embodiment of an ideal database management tool" and is supported for any SQL-type database (Charlot, 2002, p. 197). This and other designs for tools leading to effective database management will be useful in the implementation of TerpNav.

TerpNav is itself a GIS. Therefore, its interface is the main source of information for the user, it involves shortest route calculations, and it relies on database management commands to retrieve information. Understanding the ideas and important aspects of each of these four parts is essential to the success of the TerpNav project. Through our review of literature in these areas, we have gathered enough information on which to base critical decisions regarding the design, development, and implementation of the navigation system.

Sustainability

Information Systems

An information system is a general term that refers to "an integrated set of components for collecting, storing, processing, and communicating information" (Encyclopedia Britannica, n.d.). In an information system, there is a set of data, an entity that uses that data, and an entity that maintains and builds that data. The data in an information system varies greatly depending on what the system is used for. For instance, a school may have an information system that holds records of its students' grades. In this case, the teachers input grades that students get and the grades get printed out for the user—the student and his or her guardians—to see. Information system is a general term; we will define more specific terms in order to explain the possibilities of TerpNav and the challenges involved in making it work. Because one of the innovations of TerpNav is that it is a sustainable map, we will first define what a sustainable information system is.

We define a sustainable information system as an information system in which the entity that uses the data is the same as the entity that maintains and builds the data. A popular example of a sustainable information system is Wikipedia, which is an online reference encyclopedia where content can be generated and maintained by anyone who uses it (Alexa Internet, Inc., 2009). By allowing anyone using Wikipedia to update it, it has become the largest reference encyclopedia on the Internet (Wikipedia, 2009b). Sustainable information systems are able to receive free, up-to-date information from their users, but the reliability of that information has to be monitored, as it does not necessarily come from a certified source. When evaluating a sustainable information system, one must weigh the benefit of cheaper and more up-to-date information against the cost of less reliable information. In a case where reliability is very important, it might not be worth the cost of implementing a sustainable information system. In a case where data changes rapidly and up-to-date data is important, on the other hand, a sustainable information system may be a cost-efficient choice. Andrew Lih described a phenomenon he calls the *knowledge gap* in his paper “Wikipedia as Participatory Journalism” (Lih, 2004, p. 5). Traditional encyclopedias are released annually or semi-annually. Lih defined the knowledge gap as the gap in time before the latest edition comes out and where the old edition may have outdated information in it. A sustainable encyclopedia such as Wikipedia has information updated in real time, allowing fast-changing information to be disseminated quickly, thereby eliminating the knowledge gap.

Reliability

To understand whether a sustainable information system is practical, its reliability must first be determined. In a broad sense, the reliability of a sustainable information system is defined as how well the information in the information system can be trusted; however, reliability often needs to be specifically defined for each individual sustainable information system. Wikipedia, for example, has a nine-part definition that includes accuracy of information in articles, comprehensiveness, and appropriateness of style (Wikipedia, 2009a). Specific sustainable information systems will vary, so they will have different specialized measures of reliability. Reliability is commonly an issue when information in the information system relies on opinion and/or when the people editing the system do not know all of the information, either due to ignorance or because the information is complex. We will see examples of this later when we discuss Wikipedia in more detail.

To illustrate how reliability can be an issue for sustainable information systems, we will consider an analogous example. If someone wants to know how cold it is outside, one can look outside his or her window to see what people outside are wearing. Although this may provide enough information for a person to decide what to wear when he or she goes outside, it is not very reliable information. If the person he or she observed is not wearing a coat, it may be because that person does not mind cold weather, or that person may have forgotten to check what the weather was like before going out. This information might prove to be unreliable, and therefore, not useful.

The presence of more information from more sources helps to increase the reliability of a sustainable information system. In the previous example, if when looking outside, the person saw seven people with coats on and one person without a coat, the observer could come to a well-supported conclusion that he or she should wear a coat outside. A sustainable information system with more users will generally be more reliable than one with fewer users. This is not only because there are more sources who can come to a conclusion on opinionated data (as in the example before), but also because there will be more experts in various relevant areas and more people who can remove erroneous information. Reliability can be increased through a large user base; however, constraints on the user base can also be used to increase reliability.

A constraint on a user of a sustainable information system is a limit on what the user can change in the system. Constraints can be strict, such as completely preventing the user from editing anything, to light, such as allowing a qualified user to edit information that other users are not allowed to edit. Constraints allow the system to block problematic users who may be sources of vandalism. Vandalism can broadly be defined as malicious edits, which can occur in a wide variety of forms (Viegas, Wattenberg, & Dave, 2004). A user feedback and rating system is an additional method for constraining users. Such a system would create an internal system for managing constraints, as both positive and negative feedback and ratings can be used to judge an individual's contributions to the system. Users who provide quality content would be rewarded by receiving positive feedback or being highly rated; users who do not provide quality content would receive negative feedback or low ratings. Users with negative feedback and/or low ratings could then have additional constraints placed on them, meaning they would not be allowed to edit certain information, whereas users with positive feedback and/or high ratings could have the ability to edit a wider range of information. Having different levels of access to the system depending on one's record of use can decrease vandalism and increase the system's reliability.

When determining whether or not a community-sustainable information system is reliable and subject to vandalism, it is also important to consider the motives of the users and whether or not users will be altruistic when using and updating the system. Kuznetsov (2006) defined altruism as "concern for the good of others over one's own personal welfare" (p. 2). A preliminary study by Wagner and Prasarnphanich (2007) found that within users of Wikipedia, which is a prime example of a community-sustainable information system, collaborative motives dominate individualistic motives, meaning that users are motivated more by an altruistic desire to help the community than by a desire to help themselves. In addition, Kuznetsov found that "Wikipedians who are motivated by pure altruism invest time and effort into their work without any desire for compensation except for the satisfaction of giving" (p. 4). Although altruism may not be the only motive for participating in a community-sustainable information system, as reciprocity, community, and autonomy are also cited by Kuznetsov as potential motives, altruism has been shown to be a significant motive to use and update information systems.

To increase reliability most effectively, information systems should take advantage of a user's intrinsic motivations in using and updating a system, both altruistic and otherwise, rather than attempt to extrinsically motivate users. In their meta-analysis of 50 experimental studies, Tang and Hall (1995) found evidence of the *overjustification effect*. The overjustification effect occurs when an extrinsic reward is introduced when an intrinsic motivation is already present. Expected external rewards decrease voluntary participation after the reward is taken away. Therefore, once an extrinsic reward is introduced, intrinsic motivation decreases, meaning that extrinsic rewards will have to be continued in order to maintain the motivation level. Relying on intrinsic motivation that is already present in users, as documented by Kuznetsov, is more effective in maintaining user participation. In addition, creating a commitment to be altruistic when using and updating the system will also increase the likelihood that users maintain their altruistic motives. As Cialdini (2001) asserted, an initial, public commitment will create greater consistency in individuals' behavior so that they make greater concessions to maintain their commitment. Having users of an information system sign a public user statement may further increase their intrinsic, altruistic motives in using and updating a sustainable information system, thereby decreasing potential vandalism and increasing the system's reliability.

Because Wikipedia is a popular sustainable information system (Alexa Internet, Inc., 2009), we used it as a model for TerpNav, our sustainable information system. We specifically researched Wikipedia's reliability and the procedures it uses to maintain reliability in order to better ensure TerpNav's reliability.

Wikipedia

Wikipedia is a free website that allows anybody to anonymously edit articles without having to log in or make a user account (Wikipedia, 2009c). Wikipedia attempts to have its articles written in a formal tone like they would be in an encyclopedia. Articles are expected to be unbiased and comprehensive, and should contain adequate citations from reputable sources (Wikipedia, 2009a). Each article has a separate discussion page with an informal tone, which provides a forum for users with different views to come to a consensus without muddling the main article. Discussion on these pages often pertains to the comprehensiveness, validity, neutrality, and format of the article. Each article also has a separate record of the history of all changes that have been made to that article.

Giles (2005) pointed out in his article assessing the reliability of Wikipedia that an encyclopedia where anyone can edit information on the surface does not seem to be as accurate as a conventional print encyclopedia. In recent years, however, views on Wikipedia have been changing. Giles used peer review to compare the accuracy of scientific Wikipedia articles and corresponding Encyclopedia Britannica articles. Although this study found that Encyclopedia Britannica had fewer errors, the margin of difference was not large. Wikipedia has also been increasingly cited as a source in academic journal articles in recent years (Wikipedia, 2009a).

Many notable public incidents involving inaccurate information in Wikipedia articles have revolved around inaccurate biographical information. Biographical inaccuracies tend to persist because the information is often not obviously false, as there are not many people able to confirm such information. One of the biggest examples of false information on Wikipedia was an erroneous claim that John Seigenthaler Sr., an assistant to Attorney General Robert Kennedy in the 1960s, was allegedly involved in the assassinations of John and Robert Kennedy. This information was present on Wikipedia for a few months before a family member noticed and took down the information (Seigenthaler, 2005). Because this inaccurate information was biographical in nature, not many people other than family members or close friends were able to know that the information was false. In an article involving general knowledge or specific academic knowledge, there is a much larger pool of people who can accurately fix errors.

An IBM study (Viegas, Wattenberg, & Dave, 2004) addressing the effects of vandalism on Wikipedia found that although vandalism was prevalent, most of it was quickly removed. The authors concluded that "the instances of mass deletion [vandalism] were fixed so quickly that they could not be seen when revisions were spaced by date" (Viegas et al., 2004, p. 578). Wikipedia allows for such fast removal of vandalism by maintaining a history of each edit to each article. If a user finds clear vandalism on an article, he or she can go to the history of edits and restore the version of the article before the vandalism (Wikipedia, 2009c). In cases where a controversial article is being constantly vandalized, Wikipedia can also limit who is able to edit that article. In addition, Wikipedia has a research initiative that was created by motivated users to understand vandalism and its impact, and to find the most effective ways to counter vandalism (Wikipedia, 2009d).

In a sustainable information system without a large user base, more measures may be necessary to prevent vandalism. Possible methods include requiring users to log in to edit information, which will increase accountability, as demonstrated below, or having paid users who are responsible for finding and removing vandalism. The Wikipedia research initiative on vandalism analyzed 174 random articles between 2004 and 2006 in its initial research and found that 97% of vandalism was committed by anonymous editors (Wikipedia, 2009d). This preliminarily data suggests that requiring users to log in before editing a sustainable information system may be a sufficient method to prevent most vandalism. However, preventing anonymous edits entirely does result in fewer people editing and updating the sustainable information system. A study by Dartmouth College of Computer Science suggested that anonymous Wikipedia editors often provide accurate and helpful content (Anthony, Smith, & Williamson, 2007). This suggests that when vandalism can be avoided in other ways, allowing anonymous users to edit a sustainable information system may be a good decision because it allows more information to be incorporated into the system.

The study of Wikipedia as a sustainable information system gives us a good understanding of what issues a sustainable information system faces and how these issues can be addressed. Although many techniques for improving reliability and preventing vandalism would be useful for TerpNav, a sustainable map experiences different challenges than a sustainable encyclopedia. Some challenges that Wikipedia is facing, such as adding citations to articles to improve their scholarly acceptance, would not be analogous to a sustainable map. To understand how a sustainable map is different from a sustainable encyclopedia, we will define and explain the properties of a sustainable map, or a sustainable GIS.

GISs

A GIS is an information system that is applied to geographic information. The data in a GIS consists of information that is linked to coordinate points that can be displayed to the user in the form of a map. A sustainable GIS is a GIS in which the users of the GIS (or map) have an interface that allows them to change the information that is displayed on the map. There is not much literature in the area of sustainable GISs so we will define terminology regarding them ourselves. We will use these terms to help identify the unique challenges involved in implementing a sustainable GIS compared to a sustainable information system.

In our study, we are assuming that information in a GIS or sustainable GIS can generally and comprehensively be divided into two types: structures such as roads or buildings and localized information. Structures tend to be rigid in their location. Roads generally go to the same places, lakes stay in the same spot, and buildings are often erected rapidly but tend to remain in place for a long time once they are built. Localized information is nonstructural information that is added to the map and is linked to a particular location. Examples can include traffic buildup, temporary events, or construction. Localized information can change rapidly and thus is hard to display on a nonsustainable GIS such as a paper map.

As discussed earlier, sustainable information systems are more practical when data changes rapidly. A nonsustainable GIS can display structures easily and fairly accurately, assuming they are updated periodically, because structures generally do not change much. Sustainable maps, however, can theoretically be effective at displaying quickly changing localized information for little cost. Our research aimed to determine whether people using TerpNav are satisfied with localized information, primarily events and construction, which is obtained in a sustainable context (that is, by TerpNav's users).

A sustainable GIS differs from Wikipedia, our sustainable information system model, in a few ways. First, information on a sustainable GIS is harder to partition than information in an encyclopedia. Partitioning information is the process of separating information into smaller, easier-to-manage pieces. In an encyclopedia, information is partitioned into articles. Articles are generally about one topic and can be edited by people who are familiar with just that topic without having to worry about any other articles. In a sustainable GIS, the GIS can be partitioned into smaller map segments; however, each of those segments is still an integral part of the whole. If a user wants to move or change a road on a sustainable GIS, he or she will have to also change each road that connects to that road. Additionally, a feature of Wikipedia that is very useful in settling disputes is the discussion page. Each article is on a separate webpage and has its own discussion page (Wikipedia, 2009c). However, if two people disagree on the placement of a walking path, it would be hard to incorporate an analogous discussion page into a sustainable GIS because walking paths cannot be viewed individually on their own webpages. Similarly, the ability to track changes to a sustainable GIS is more challenging, as a change to one structure on the map will most likely change structures nearby. We are assuming that the history of changes for a certain area of the map will be much larger than the history of changes for a single Wikipedia article.

Whereas updating structures in a sustainable GIS is challenging, updating localized information in such a way is much easier. Localized information should be able to be easily partitioned because it usually involves a single location and does not depend on nearby information. If two events are taking place in the same building, a change to one event most likely will not cause a change to the other event. Additionally, localized information can have its own window with information, which provides an easy way to incorporate an analogous "discussion page" if people disagree with or need clarification on that information. When dealing with localized information, many of the techniques used by Wikipedia can be used to increase the reliability of a sustainable method of obtaining and maintaining localized information. Finally, because localized information changes rapidly, a sustainable GIS may be the only cost-effective method for comprehensively providing that information. We incorporated these findings into the development of TerpNav, as you will read in the Phase One and Phase Two Design and Development Processes.

Discussion

As part of the product development process, it was important for us to review the pertinent literature in the three areas of our research: accessibility, interactivity, and community sustainability. Our literature review helped us to realize that there is a need for pertinent, reliable, up-to-date information about wheelchair accessibility.

First, we reviewed government documents such as the Americans with Disabilities Act of 1990 in addition to newspaper articles in order to better understand the needs of people using wheelchairs, our target user base (U.S. Department of Justice, 1994). We used this information throughout the development of TerpNav.

In addition, Team FASTR discovered a multitude of technical sources related to the interactivity of GISs. We reviewed academic sources related to the interactions between the user and the information system through the graphic user interface that we used while designing TerpNav. We also reviewed sources detailing the best way to design and maintain a large database of geographic information. In order to determine the best way to provide the fastest point-to-point route finding, a review of the literature surrounding Dijkstra's algorithm was performed. As part of this search, we also found many improvements and proposed enhancements that had been made to the basic algorithm, which is useful information for the development of our system.

We also performed a review of currently operating community-sustainable systems. Our main basis for community sustainability comes from our model system, Wikipedia. Through analyzing Wikipedia, we were able to examine major issues affecting community-sustainable systems such as user participation, vandalism and ways to combat it, and parallels between regular information systems and GISs.

The focus of our research from the literature review forward was to validate the information we found by performing interviews of our target population, creating a mapping system with which to implement our findings, and surveying users of our system to determine its efficacy. We were then able to gather data directly from the system in order to further answer our research questions.

Chapter 3: Study of Other University Maps

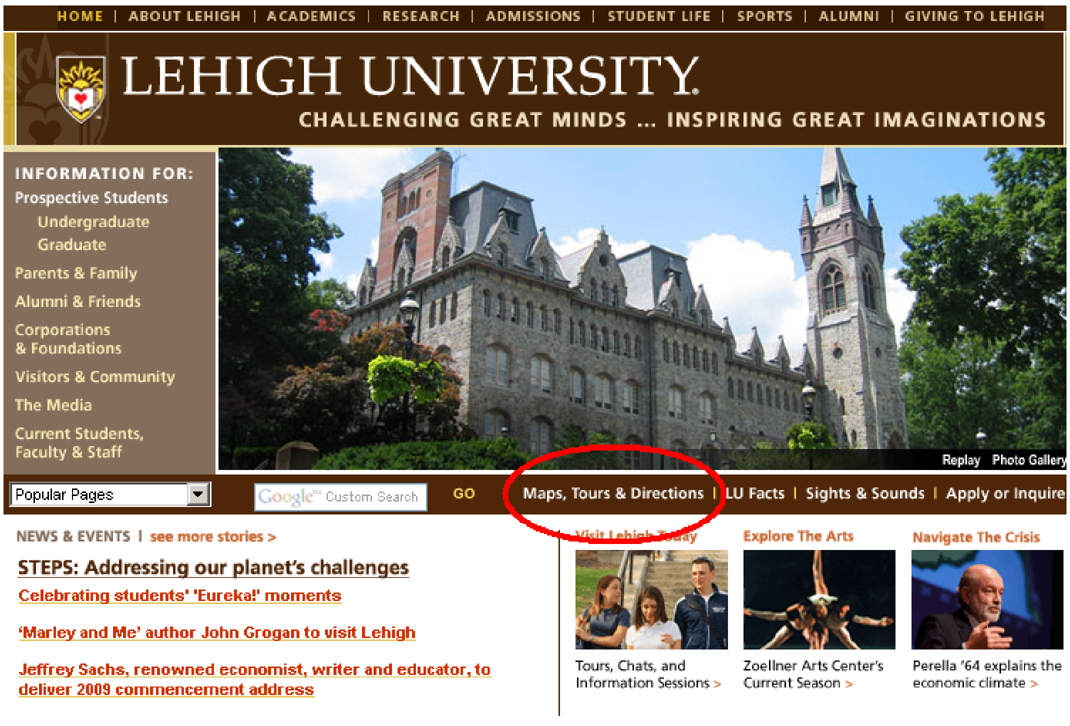
Method

In order to assess how other university maps were addressing our goals of accessibility, interactivity, and sustainability, Team FASTR completed a comparison study of campus maps of the 90 top universities in the United States, according to *U.S. News and World Report*'s "Best Colleges 2008," to determine the types of features and information that should be available on TerpNav (*U.S. News and World Report,* 2008). The procedure for collecting the maps and usable data from the maps is outlined below. A randomly chosen example, Lehigh University—at number 30 in the *U.S. News and World Report*'s rankings—will be used as an illustrative example. For each map's data collection, we attempted to mimic the typical user experience of a visitor to a particular university's campus. It was important to attempt to mimic a real user experience because most visitors do not have special information or skills that would enable them to know anything about a university campus other than the information that is publicly available on a university's website. If an especially useful map exists, but is unavailable to a normal Internet user, it is likely that we did not survey it, favoring instead a more readily available map that a user might consider adequate. We followed hyperlinks no more than two webpage jumps from the map in order to mimic the browsing habits of an individual who is primarily concerned with the map. All of the procured data for each university map was then compiled and tabulated to better help us create our own map (for the complete spreadsheet of university maps, see Appendix B).

The first step in our process was to navigate an Internet browser to the main website of one of the universities. In the example, Lehigh University's main website can be found at http://www.lehigh.edu. A preliminary visual search of the main webpage was performed to find a hyperlink to a campus map. Lehigh University's front page includes a link to "Maps, Tours & Directions" (see Figure 1). If such a link was readily available, as it was on Lehigh's webpage, we followed it; however, in the absence of an obvious front-page map link, the team tried several other methods to find the university's map. The first method was to perform a keyword search in the university-provided "search" space. Common search terms included "map," "campus map," "wheelchair map," "ADA map" (where ADA stands for Americans with Disabilities Act) and "interactive map." When more than one map of the university was discovered, the team focused on the map with either more information for people who use wheelchairs or the map that appeared to be the most interactive. When both maps with information for people using wheelchairs and an interactive map were available, we chose to collect data about the map with information for people using wheelchairs.

Figure 1: Lehigh University Main Webpage

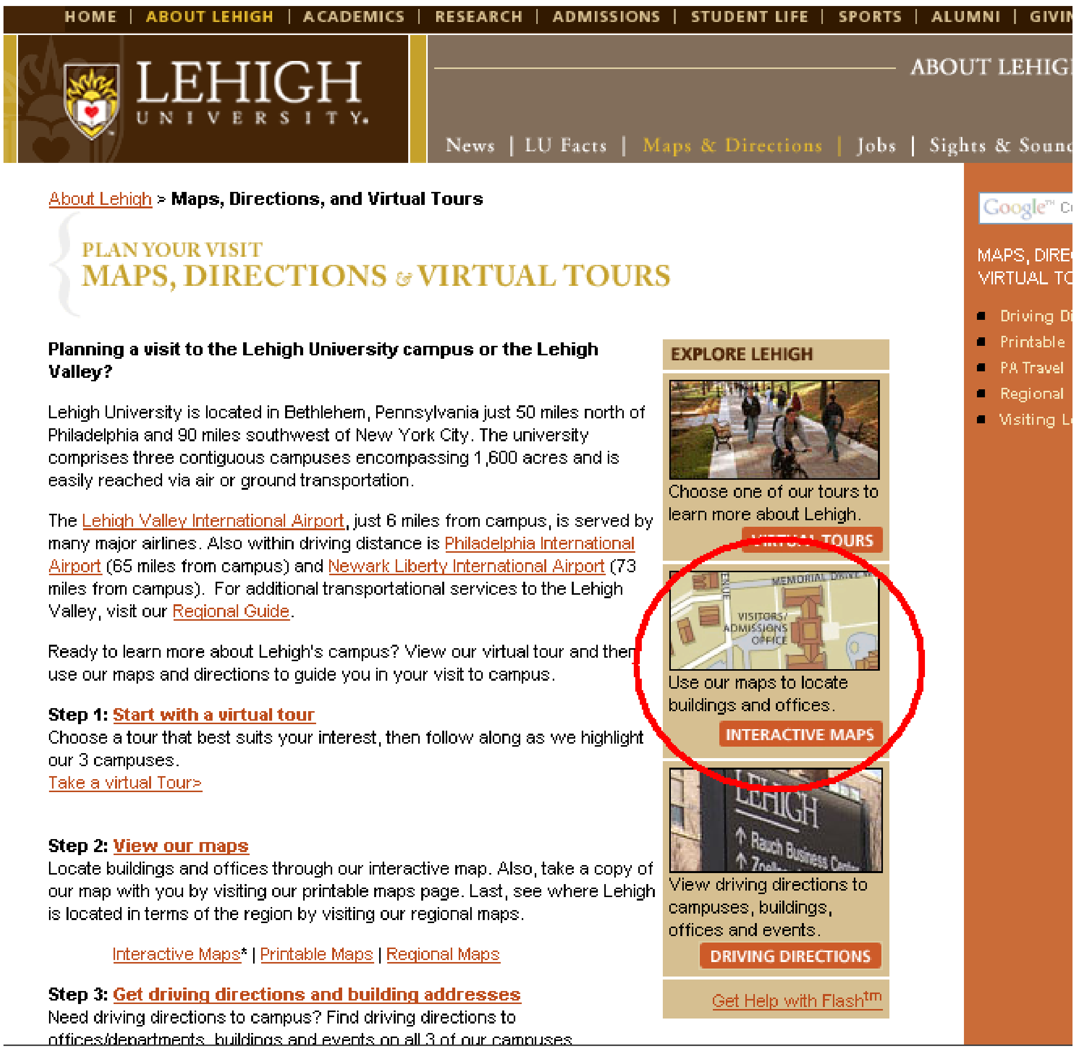
This figure displays the main webpage of Lehigh University. A hyperlink to “Maps, Tours & Directions” is highlighted. Image acquired from http://www3.lehigh.edu/default.asp, retrieved February 19, 2009.



Following the “Maps, Tours & Directions" link on Lehigh University’s main webpage, we chose to collect data on the “interactive map” because no obvious wheelchair map was available (see Figure 2). After clicking on the link to Lehigh’s map, we were brought to an Adobe Flash media-based webpage with the URL http://www.urisldev.net/media/maps/.

Figure 2: Lehigh University Main "Maps, Directions, and Virtual Tours" Webpage

This figure displays the "Maps, Directions, and Virtual Tours" webpage that appears after clicking on the link on the Lehigh homepage (see Figure C1). The Lehigh University "Interactive Maps" hyperlink is circled. Image acquired from http://www3.lehigh.edu/about/maps/default.asp, retrieved February 19, 2009.



Upon navigating to any university's map, Team FASTR judged the interactivity of the map based on several factors. Some of the main factors of interactivity judged included whether a user is able to click on a building to obtain more information about the building; whether the map includes a readily available search function; whether the map provides a way of layering information to enable users to show and hide information at will; and whether the user is able to zoom, pan, and/or scroll to navigate through the map.

Each map was assigned to one of three categories: Portable Document Format (PDF) maps, which are static digital representations of paper maps; satellite maps, which use popular satellite-mapping technologies such as MapQuest or GoogleMaps; and drawn maps, which are comprised of digitally drawn maps, some that are interactive and others that are not.

Lehigh University's map was classified as a "drawn map," one of 54, and further classified as "interactive" because of its ability to zoom and pan the map pane, click on the buildings for more information, layer new information on top of the map, and search for buildings by name (to see the search, zoom, and layering functions in the screenshot of Lehigh's map, see Figure 3).

Figure 3: Lehigh University Map

Lehigh University's map allows users to search, zoom, and toggle parking and wheelchair access layers. Image acquired from http://www3.lehigh.edu/about/maps/interactive/index.html, retrieved February 19, 2009.

To further determine the available information about buildings, we attempted to click on a building and noted whether information about the building appeared when the building was clicked on. In order to be considered "clickable," we determined that information that was not already on the map must be apparent only after deliberately choosing to see more building information. In all instances, this meant that a user must either click on the building itself and/or on the name of the building from a list. We also looked for icons within the outline of the buildings that might have denoted clickable items of interest within the building.

On Lehigh's map, the buildings were clickable, which provides users with information about each building, as well as links to departments within the building (for an example of a clicked building in a screenshot, see Figure 4). Lehigh's map also featured an information-layering feature, which was used to show wheelchair entrances and handicapped parking (see Figure 5).

Figure 4: Lehigh University Map Building Pop-up

Lehigh University's map provides a visually appealing "pop-up" box that displays information about a clicked building. The red square has been added to denote the building information. Image acquired from http://www3.lehigh.edu/about/maps/interactive/index.html, retrieved February 19, 2009.

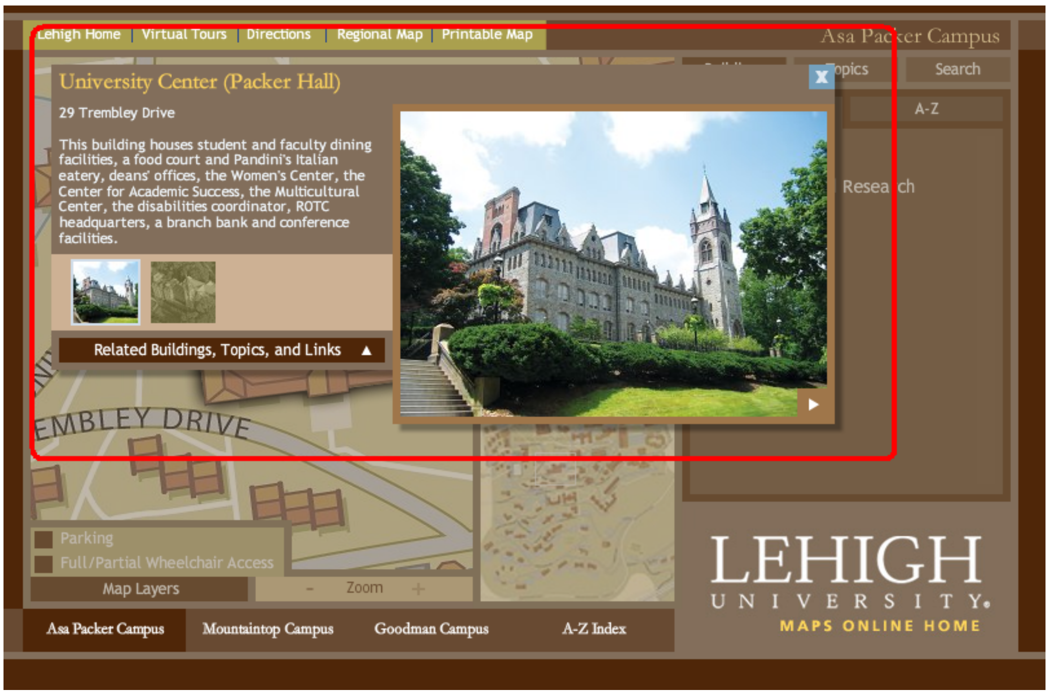
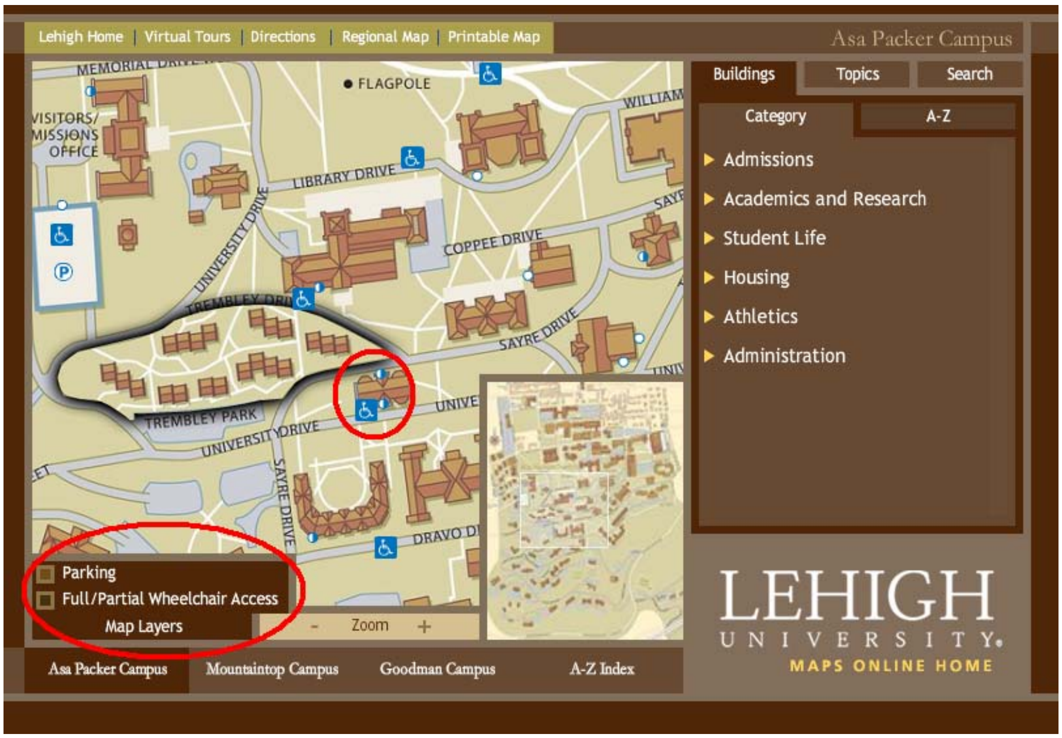


Figure 5: Lehigh University Map Accessibility Features

Lehigh University's map shows wheelchair parking and full or partial access to buildings. Examples of the symbols used are circled. Image acquired from http://www3.lehigh.edu/about/maps/interactive/index.html, retrieved February 19, 2009.



Team FASTR searched all maps for evidence of details such as construction sites, wheelchair entrances to buildings, handicapped parking, and varied information concerning accessibility inside buildings. Lehigh's map did not give any notice of construction on its campus. When no construction sites were observed on the map, we then looked for the map's key to determine whether the map had any indication of ever providing information about construction. The same process was used for evidence of wheelchair entrances and handicapped parking. We also looked at each map to see whether the map included a distance-determining feature. Lehigh's map did not include a feature for determining the distance between two points on the map.

It is Team FASTR's belief that community sustainability can be used to create more accurate and more information-rich maps. In order to determine the level of community sustainability that was present on each map, we searched for several indication features. We first searched for whether each map included a timestamp for when it had last been updated, and whether there was a readily available way to report an error on the map. We also looked for any instances of user input, such as errors, notes, or events. We discovered that Lehigh's map did not include a timestamp for when it was last updated, and neither did it provide an easy method for informing the appropriate authority that the map may be incorrect. We also found no way for a user to input information into the map. Overall, Team FASTR determined that although Lehigh University's map was very interactive, it lacked important accessibility and community-sustainability features. Lehigh University's map is used as an example of the process that we went through for all 90 maps, which provided information on current university maps around the country.

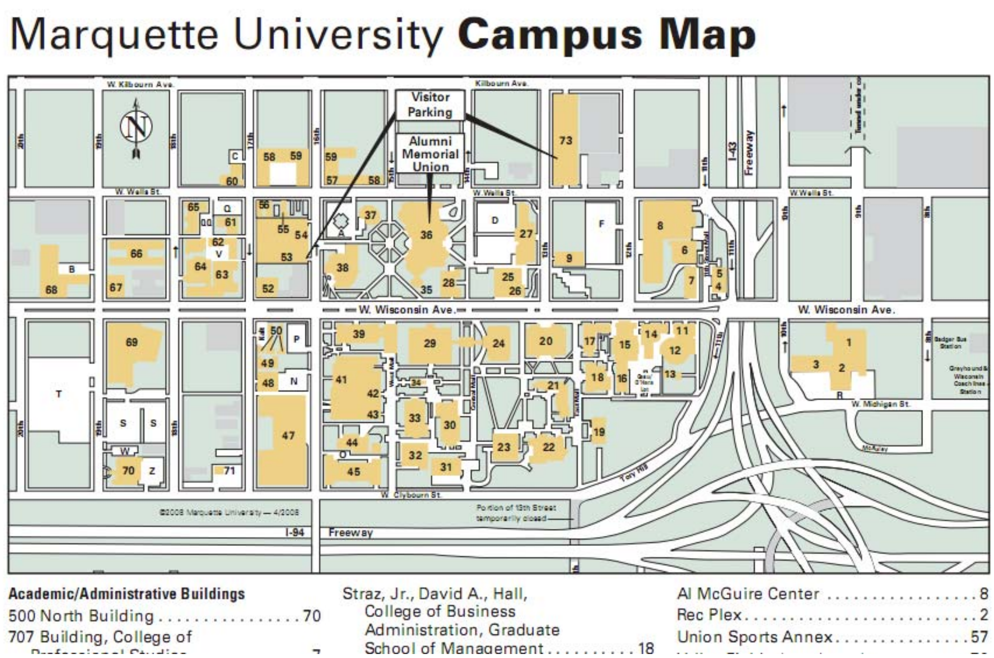
Results and Discussion

Interactivity

As discussed earlier, maps were classified as either PDF maps, satellite maps, or drawn maps. An example of a PDF map can be found at Marquette University at http://www.marquette.edu/about/documents/CampusMap.pdf (see Figure 6). This map provides no specific information other than building names. Usually, the least interactive of the maps were the PDF maps. PDF documents require an extra software program such as Adobe Reader to be viewed. PDFs are not interactive, and can only be zoomed and panned. For any additional information about a building, for example, a user must use a different source than the map.

Figure 6: Marquette University Map

Marquette University's map is a portable document format (PDF). The only available information about any building is the building location and name. Image acquired from http://www.marquette.edu/student/ugrad/campusmap.shtml, retrieved February 19, 2009.



Both the satellite and the drawn maps categories had examples of very interactive and barely interactive maps. The most interactive maps allowed the user to hide and show information, and to zoom, pan, scroll, and search. A prominent example of an excellent interactive map is Iowa State's map. Iowa State's map provides pan/zoom functionality, as well as layering of information such as building names, accessibility, and construction (see Figure 7). The least interactive maps were little more than digital pictures of paper maps. An example of a barely interactive drawn map is the University of Pittsburgh's campus map (see Figure 8). The font on each building is too small to be read with a normal computer screen resolution. With no option to zoom in, the user is forced to haphazardly click on the map to see the name and description of buildings. There is no extra information about the buildings available on the Pittsburgh map, nor is there a good way of displaying it. Most maps that we surveyed included some but not all of the interactivity features.

Figure 7: Iowa State University Map

The Iowa State University map allows users to pan/zoom, search for buildings, and toggle layered information. Image acquired from http://www.fpm.iastate.edu/maps/, retrieved February 19, 2009.

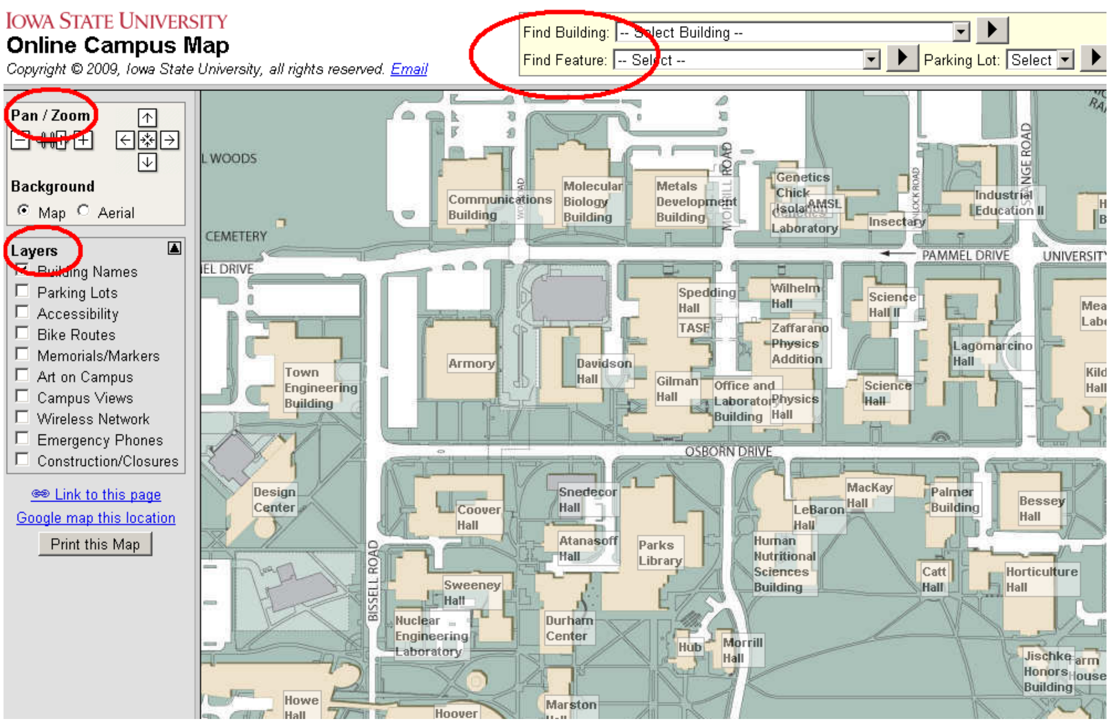


Figure 8: University of Pittsburgh Map

The University of Pittsburgh Map is a “drawn” map with limited functionality. Image acquired from http://www.upj.pitt.edu/401/, retrieved February 19, 2009.

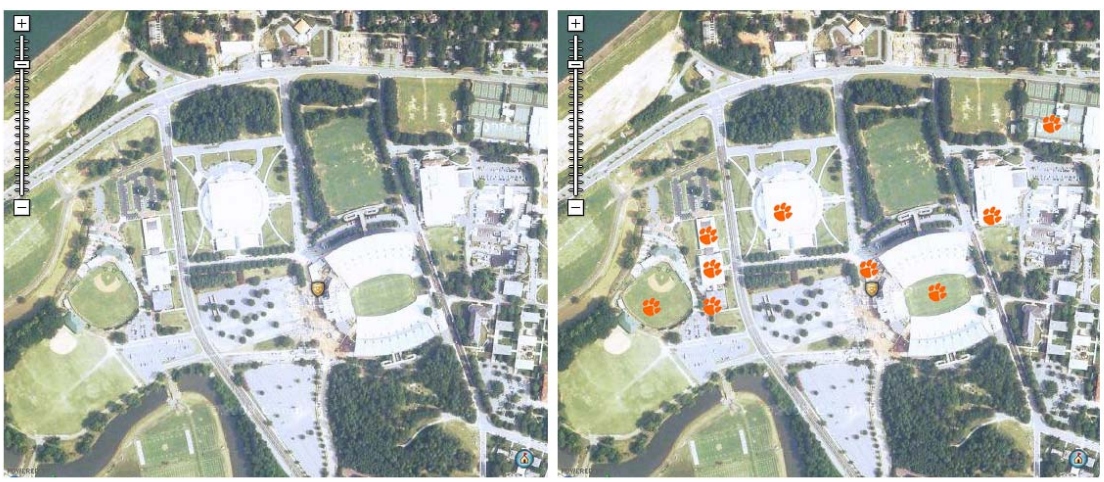
Among the maps with clickable buildings, there were 29 maps that provided pictures of the clicked building, and 27 maps that listed information about the departments or services in the building. Half (45) of the maps provided no information about buildings—most of these maps were in PDF format.

Another interactive feature, a search function, is also a powerful way for a user to find information fast. Only 30 of the campus maps offered a search function, and 15 campus maps required users to scroll through lists of buildings to find what they were looking for. Scrolling through a large list can be just as frustrating for a user as not having a search feature. The other 45 maps included no search functionality at all.

Twelve university maps included a layering functionality. A good example of layered information is shown in Clemson's map, where information about athletic facilities is denoted by orange paws on the right map but not on the left map (see Figure 9). Although there were different levels of interactivity in all of the maps we studied, we were not able to find a map that included all of the features of interactivity that we were looking for.

Figure 9: Clemson University Map

Clemson University's map allows users to toggle layers. In the screenshot on the right, the "Athletics" toggle has been activated, and users can see Clemson Tiger paws denoting athletic facilities. Image acquired from http://www.clemson.edu/campusmap/2007_11x17map.pdf, retrieved February 19, 2009.



Accessibility

After judging the interactivity of each map, Team FASTR then looked at the content of the map to determine the level of accessibility information that was available. We searched for construction sites, wheelchair entrances to buildings, handicapped parking, and indoor mapping information.

A total of 31 maps showed wheelchair-accessible entrances, and 32 maps provided information about handicapped parking. Less than one quarter (20) of the maps analyzed provided information about wheelchair-accessible pathways. In determining whether a map denoted wheelchair-accessible entrances, we looked for an easily recognized symbol at each of the wheelchair-accessible entrances. Merely stating that a building is handicapped accessible was not considered adequate in our study to be considered as denoting wheelchair-accessible entrances. Boston University's map displays many wheelchair-accessible entrances layered on its map (see Figure 10). Often, a building that was labeled as handicapped accessible did not actually show a user where the wheelchair-accessible entrance was on the map, as one can see in Wisconsin University's map (see Figure 11). In order for us to have considered a map as having wheelchair-accessible pathways, it needed to clearly show a user where a wheelchair can and cannot travel. All too often, we found that the accessibility information available on university maps was inadequate.

Figure 10: Boston University Map

Boston University's map allows users to toggle information about wheelchair-accessible entrances, touch-tone enabled payphones, audible crosswalk signals, and curb cuts. One can see the symbols on the map for wheelchair-accessible entrances. Image acquired from http://www.bu.edu/maps/, retrieved February 19, 2009.

Figure 11: Wisconsin University Map

Wisconsin University of Wisconsin–Madison's map provides users with an "Accessibility" hyperlink, but no accessibility information. Image acquired from http://www.map.wisc.edu/, retrieved February 19, 2009.

Only 12 of the maps surveyed provided any information about construction happening on the campus. Iowa State's map provides a good example of using layering to show construction (see Figure 12). Only two maps were able to calculate the distance between two points on the map, and this functionality was limited to straight-line calculations such as on the University of Florida map (see Figure 13). In a straight-line calculation, distance is calculated by connecting a straight line through two user-selected points. Accordingly, pedestrians using the University of Florida map may be unpleasantly surprised that the distance traveled is considerably greater than the straight-line calculation. No surveyed maps were able to calculate routes along pathways. The ability to calculate and display accurate routes along pathways, which we wanted to provide with our navigation system, sets TerpNav apart from other university maps.

Figure 12: Iowa State University Map Depicting Construction

Iowa State University's map allows users to see where there is construction. The symbol is circled. Image acquired from http://www.fpm.iastate.edu/maps/, retrieved February 19, 2009.

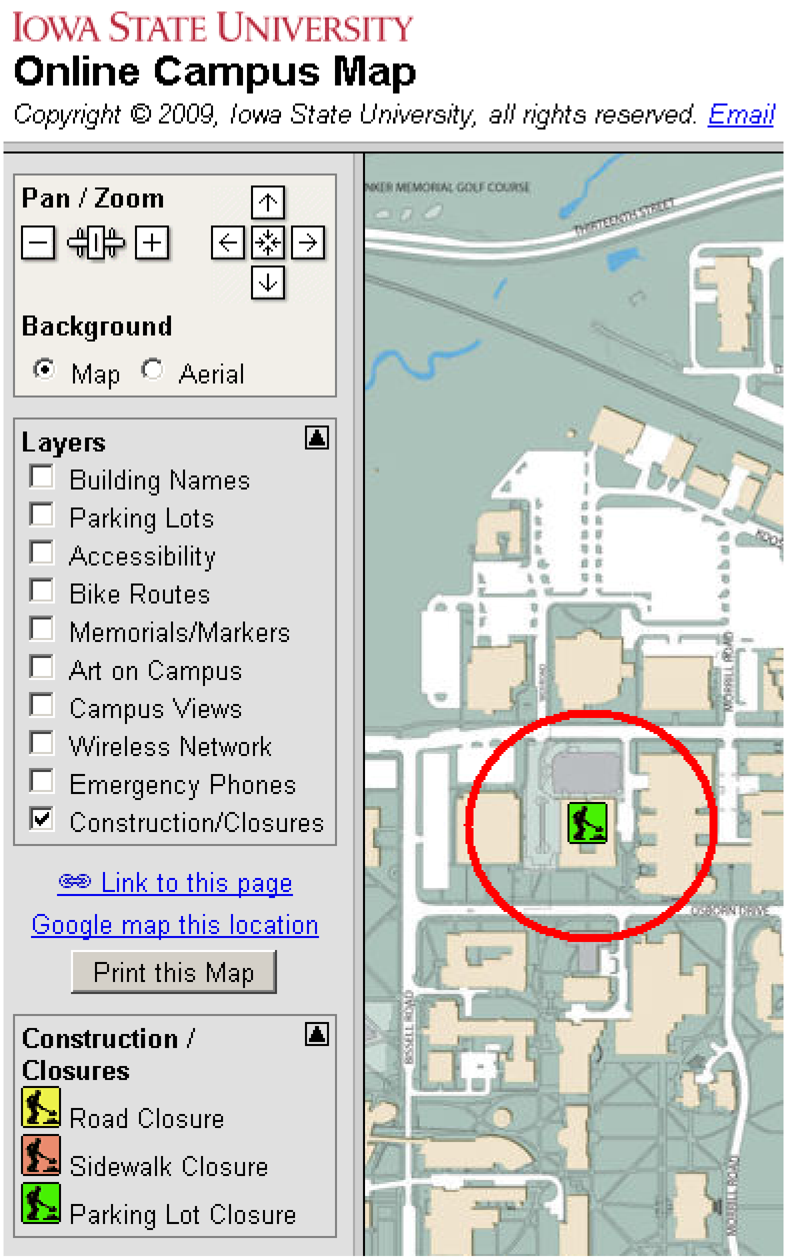
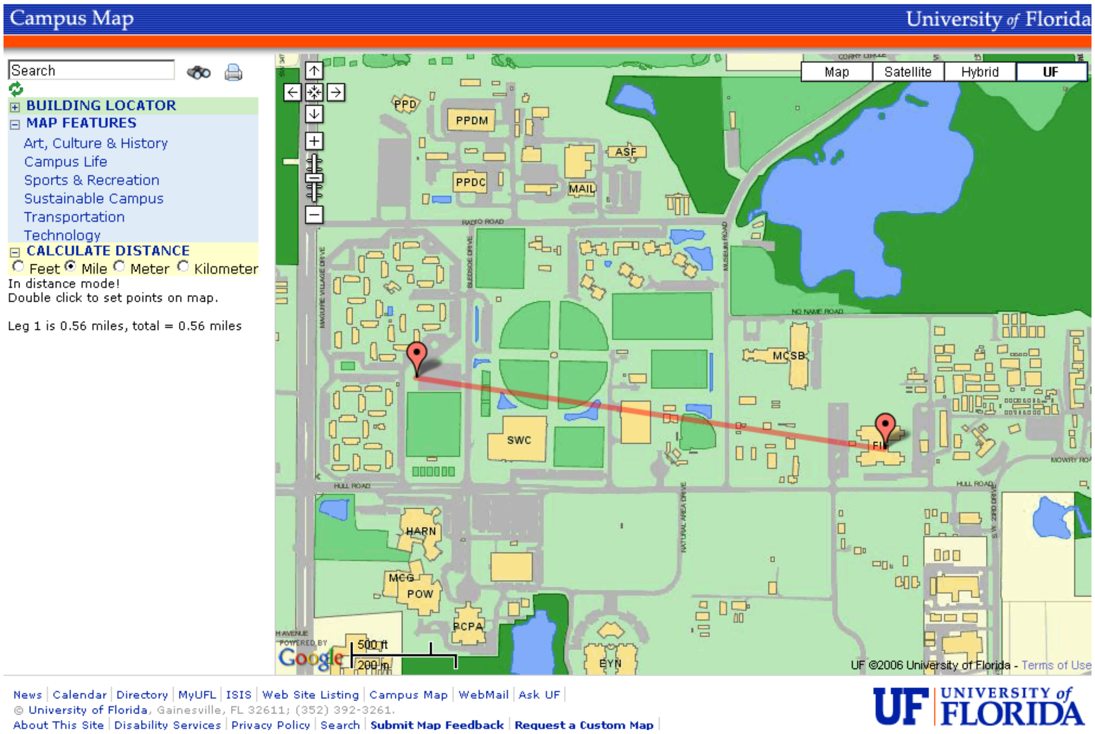


Figure 13: University of Florida Map

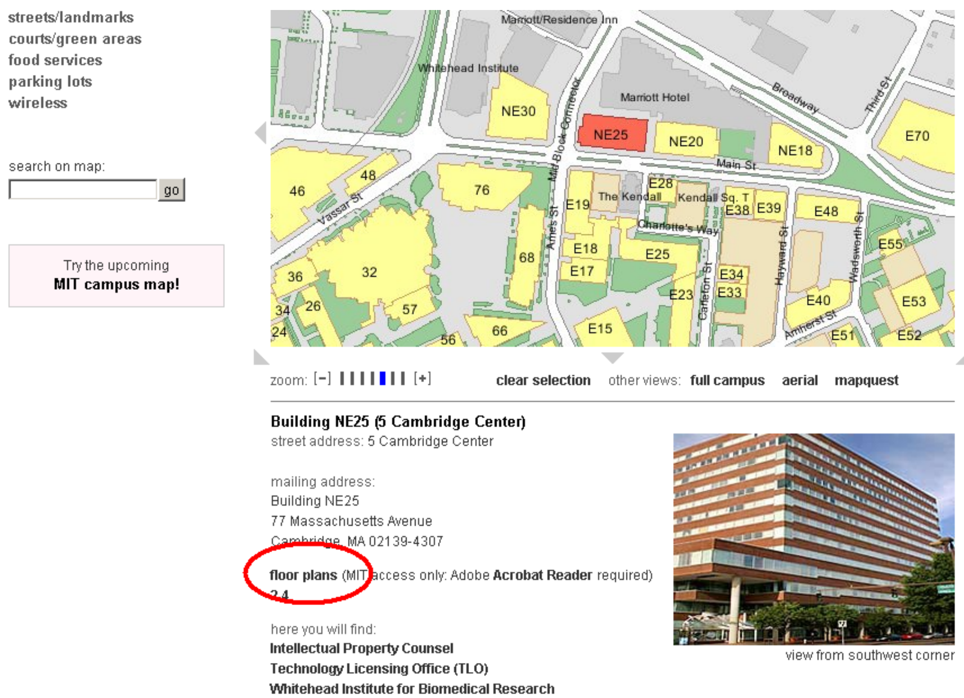
Although the University of Florida's map calculates distances, it only calculates the distance between two points based on a straight-line calculation, rather than following the paths. Image acquired from http://campusmap.ufl.edu/, retrieved February 19, 2009.



Finally, we noticed that some of the maps included indoor navigation information about elevators (13 maps) and restrooms (two maps), and three maps provided links for building floor plans, as illustrated in this map from the Massachusetts Institute of Technology (see Figure 14). Although some university maps attempted to provide accessibility information, and some were successful at providing detailed information, most maps studied lacked the detailed accessibility information that was desired and is present in TerpNav.

Figure 14: Massachusetts Institute of Technology Map

Massachusetts Institute of Technology's map provides direct hyperlinks to building floor plans. Image acquired from http://whereis.mit.edu/map-jpg/, retrieved February 19, 2009.



Sustainability

None of the maps surveyed allowed users to edit any portion of the map for their benefit. In addition, none of the surveyed maps allowed users to put events on the map, nor did any map allow users to make notes on the map for other users to view. Of the maps studied, none provided any method of incorporating user input beyond e-mailing a webmaster, which is a common feature for any website but not necessarily a measure of community sustainability.

Discussion

The maps of the 90 top universities in the United States that we studied provided similar functions. All of the maps provided the very basic spatial relationship between buildings, landmarks, and geography. Starting from this base level, many of the college campus maps included much more information. Some maps provided information about the buildings and important landmarks, and some maps even provided pictures and descriptions of buildings. Several maps included information for people who use wheelchairs, such as wheelchair-accessible entrances and the location of accessible parking spaces.

As the designers of a new interactive mapping system for the University of Maryland, Team FASTR used the information gathered from surveying the maps of the top universities in the United States to determine which features we wanted in our mapping system. We found features that we knew would be very important for a successful interactive map, such as the ability to pan, zoom, and click, but we also noticed major shortcomings of the information available on most campus maps. The most notable shortcoming was the consistent omission of wheelchair-accessibility information and the ability to route direct pathways from one location to another. We also noticed the complete lack of any community sustainability in any of the university maps. None of the maps provided user input beyond a standard “comments to the webmaster” e-mail address. After concluding this study, we wanted TerpNav to be different. Unlike the majority of the maps studied, we wanted TerpNav to be interactive, community sustainable, and accessible to our user base—people using wheelchairs.

Chapter 4: Interviews

Method

To find out more about our proposed community-sustainable navigation system's user base and its needs, we interviewed people who use wheelchairs regarding the need for a new navigation system, specific features to be included in the system, and the possibility of a sustainable system. Before beginning our interviews, we applied for and received approval from the Institutional Review Board (IRB), as is required for any campus research study directly involving people. Then, we advertised for interview participants primarily on the University of Maryland's Disability Support Services (DSS) listserv, but also on regular university listservs and with fliers around campus. From our advertisements, we were able to set up interviews with six people who use wheelchairs and whose names must be kept confidential due to IRB requirements. Among the six individuals were three undergraduate students, two graduate students, and one visitor. There were four female participants and two males. The interviews took place on the University of Maryland College Park campus in locations that were convenient to the participants. After the participants read and signed the consent form, we then began the interviews. All participants were asked the same questions and received the same prompts, including a general description of the navigation system we were proposing and a description of the proposed sustainable aspect of the system (see Appendix C). Two interviewers were present to conduct each interview. One interviewer asked questions while the other took notes and monitored the audiotape player. All interviews were audiotaped and later transcribed. In return for their participation, the interviewees were given $25 gift cards to the University Book Center.

The interviews consisted of both open-ended and close-ended questions, although we tried to keep most questions open-ended to allow for a variety of responses. Example questions included, “What conditions would you want the system to consider when choosing a path?” and “What would motivate you to update the system?” With most of the open-ended questions, we included possible prompt ideas in case the participant was unsure of our meaning or could not think of possible answers to the question. Given that the interviews were part of our data-gathering component of the product development methodology, we tried to gather the most data possible, without limiting any answers in choosing the methodology or in forming the questions. We also tried to enter the interviews without making any assumptions on what the outcomes would be.

Results and Discussion

We conducted the interviews in order to answer our first research question: “What do people using wheelchairs require from a community-sustainable navigation system?” Before conducting any interviews, we hypothesized that people who use wheelchairs would be willing to use and update the system. We also hypothesized that people who use wheelchairs would feel more comfortable with a map that could only be updated by certain users, such as registered users who had achieved a good rating from others. Lastly, we predicted that people who use wheelchairs would update the map mainly to help themselves and others who use wheelchairs.

After conducting the interviews, we found that some of our hypotheses were correct, and others were not. Many of the interviewees said that they would be very willing to use and update the system, and that it would be very helpful in getting around campus. Some people said that the sustainability aspect would be especially useful when a certain accessible path is blocked, because finding this out ahead of time from the online mapping system would save a lot of time that would otherwise be spent backtracking to find another route. However, whereas some people said that they would trust a small community of registered users to update the map, others said that they would only trust an administrator to update the map. Finally, we were correct in predicting that people would be willing to update the map in order to improve it for others to use.

Need for the System

As mentioned earlier, the interviews included both close-ended and open-ended questions in order to answer our research question and to confirm the need for a navigation system addressing the needs of people using wheelchairs. By asking close-ended questions, we gained quantitative data regarding the need and purpose of our proposed system. For instance, all six of the participants believed that there was a need for a navigation system like the one we were proposing, referred to in the interview questions as "a computer software program that will aid the navigation of people with disabilities, specifically people who use wheelchairs, by generating wheelchair-navigable routes of travel on the University of Maryland College Park campus." Although our research assumed that there was a need for a system like TerpNav, called "GeoWiki" during the interview stage, it was reassuring to find that people using wheelchairs also felt that there was a need for this system. All of the participants in the study also stated that they would be willing to use the system and that it would improve their everyday life, again confirming the purpose of our research. Five out of the six participants stated that they believed the system would alleviate their current navigation problems and would have a long-term impact on the University of Maryland College Park campus and the surrounding community. Five of the interviewees also stated that they would be willing to update the system if it was community sustainable, meaning that users could freely edit it to keep up with changes around the campus. These close-ended questions helped to solidify the purpose of the study and show that it was a worthwhile endeavor, leading us to pursue the next stage of the product development process.

The open-ended interview questions also addressed the need for a system, as questions like, “Do you have any difficulties in navigating the campus now? If so, what?” prompted answers that addressed the need for a system like TerpNav. In answering this question, one participant said, “There [are] a lot of times I go a certain way and then, I get there and I realize there’s steps at the bottom and I have to turn around and go all the way back.” This response illustrates a need for a navigation system that provides accurate real-time information regarding obstacles in paths such as stairs or curbs. According to another participant, “If you take the sidewalks, they have curbs you can get on, but at the end of the sidewalk, there’s no depression in the concrete for a ramp. So I have to turn back around, go back the way I came, and go back on the street or a different way.” People using wheelchairs cannot go down stairs or curbs, meaning they need to know the locations of such obstacles ahead of time in order to avoid routes containing them.

Features

The interview responses also contained common themes regarding what features were important to include in a navigation system for people using wheelchairs. Five out of six participants mentioned including the locations of handicapped bathrooms and steep hills. Four out of six participants believed that it is important to note where construction is occurring, and two out of six participants mentioned paths with curb cuts, handicapped entrances and exits to buildings, and steps and stairways. These responses addressed our first research question, displaying that people using wheelchairs would like to see the features mentioned above included in a navigation system.

Interface

Participants also commented on the interface of the proposed system. One participant stated, “I think you need to make it easy to use and very intuitive, where you can’t expect somebody to spend a lot of time inputting” information. The system we designed would have to be user friendly and easy to understand so that people would actually use it. Otherwise, as this response shows, the system might not be used by our target user base. Another participant said, “I don’t want somebody to not be able to use it because they don’t have the money to buy a GPS system. Make sure it’s printable.” This response displays a theme that was common throughout the responses: Participants favored a web-based system that could be printed. In terms of interface, participant responses displayed the importance of having a user-friendly system that was available to the most users possible.

Sustainability

The interview questions also dealt with the sustainability of the proposed system, which is addressed in the second research question, “How will we develop a community-sustainable navigation system that addresses the needs of people using wheelchairs?” In answering the interview question, “What could improve the sustainability of the system?” one participant stated that it “just needs to have the input of people who are going to use it as much as possible.” Another respondent said, “Because the university is such a transient place, that students come and go every four years, there has to be a commitment, like a constant commitment, from the university. And it might need some funding.” These answers address the research question of how we would develop a system to address the needs of people using wheelchairs, as they show that having user input as well as a commitment from an organized body such as the University of Maryland are both very important to keeping the system sustainable.

The sustainability interview questions also addressed the last research question, “What properties of the community-sustainable system will enable and attract participation by the community?” Regarding issues of trusting a system that could be changed by other users, one participant stated, “It would probably be better to maybe have users be able to type in input but not necessarily change the map. I think it would be better just to have them tell…a main person who changes the maps…for them to be able to give verbal input or written input to the changes.”

Overall, it seemed as if the participants were unsure about trusting a system that could be changed by others. Many seemed to like the navigation system idea but did not know what the actual outcome would be. We took these concerns into consideration when designing and developing our prototypes.

Effects of the System

The interview responses revealed a theme relating to the effects of the proposed system if it were developed and used on campus. As one participant said, “I think the campus would grow in diversity as well as just in general, because there are so many other schools who are more accessible but this is a great school.” Another participant had a similar opinion, stating, “I think it could really improve the campus. It might even improve the likelihood of people with disabilities applying to the University of Maryland and coming here.” These responses reinforced the purpose of the proposed system, showing that it will not only help individual users but the entire campus community as well.

Possible Biases and Conclusions

As only six people were recruited to participate in our interviews, it is possible that the above results are not based on a representative sample of the population. Only one visitor to campus was interviewed, so most conclusions were drawn from people who were already somewhat familiar with the campus. It is possible that we would have drawn different conclusions if the sample of people interviewed was larger and more diverse. We did, however, take our conclusions into account when designing the first version of TerpNav. At a minimum, we needed a system that could take a starting point and an ending point on campus and plot the shortest route between them.

Because one of our first priorities was to make a map of wheelchair-accessible routes, we also decided to have filters, which would allow the user to find a route that did not have stairs, only used curb cuts, and/or avoided steep inclines. We also wanted a “Find Locations” feature, where the user could type in the name of a building or specific area, see where on campus it was located, and see details about it. Only handicapped bathrooms were left out of the system because the actual development of TerpNav did not include an indoor navigation component as was proposed during the interview cycle. The details of our design and development process are included in the next chapter.

Chapter 5: Phase One Design and Development Process

Method

In order to design the first navigation system prototype, we synthesized the results from the study of other campus maps and the interviews with our own ideas regarding the appearance and functionality of the system. The team began the design process by first describing what we wanted the system to look like and how we wanted it to function. This was followed by creating concept screenshots visually depicting how we wanted the system to appear and what features we wanted it to include (see Appendix D). Then, given that none of Team FASTR's members had extensive computer science knowledge, we contracted out the development of the navigation system to multiple Software Engineering at Maryland (SEAM) teams. The SEAM teams consisted of upper level undergraduate students working on computer programming projects for outside clients. For two of these teams, Team FASTR was the client.

We contracted two teams, one for the outdoor component of our system and one for an indoor component, which was never actually incorporated into our system due to difficulties in developing it by our time schedule. The main responsibilities of the SEAM teams were to develop route-calculating abilities and design the system interface that users would see when accessing the system. The SEAM team working on the outdoor component developed the first prototype of what we now refer to as TerpNav based on our designs in May 2008. Several individuals within the University of Maryland Computer Science Department then fine-tuned the system while members of Team FASTR checked the accuracy of the mapping data in the summer of 2008, preparing TerpNav for its first rollout within the desired user community.

Results and Discussion

Per our design specifications, the SEAM team responsible for the outdoor component completed the first phase of the TerpNav development in spring 2008. The prototype incorporated the designs and functionality that Team FASTR had provided during the brainstorming process, which reflected the results of the interviews, literature research, and our own ideas of how TerpNav should function, combined with the route-calculating algorithms and user interface developed by the SEAM team. The design and development phase of TerpNav addressed our second research question—"How will we develop a community-sustainable navigation system that addresses the needs of people using wheelchairs?"—because it encompassed the design of the system as well as the software development and functionality aspects of the program. It was important to develop the most optimal system that catered to the needs of our target population—people requiring mobility assistance—as well as the University of Maryland campus community as a whole.

Base Map

When developing TerpNav, we first needed to decide on a base map that contained preliminary data on the University of Maryland College Park campus. We wanted a source that allowed us to alter and update the map data, including the ability to add new paths or buildings to the map without needing constant permission from the owner. Also, because we wanted the system to determine the most optimal walking path between two points, we needed the map to have other options besides roads that could be delineated as pathways. Because of these requirements, programs such as GoogleMaps and MapQuest were not optimal choices for our base map due to copyright obstacles and their focus on automobiles, not pedestrians. We decided to use OpenStreetMap (openstreetmap.com), a global map that can be updated by any user who is connected to the site and registers for a username (OpenStreetMap, 2009). OpenStreetMap creates, hosts, and provides "free geographic data such as street maps to anyone who wants them" (OpenStreetMap, 2009). Upon accessing OpenStreetMap for the development of TerpNav, we discovered that the map already had a basic image of the University of Maryland College Park campus, including a general outline of building and road placements. Due to the nature of the website, we were able to manipulate the map by adding paths, buildings, stairs, doorways, parking garages, and other points of interest to the campus map.

TerpNav Programming

After determining that OpenStreetMap was a suitable base map and adding the necessary mapping data, we then needed a program to determine the shortest route between two points on the map, given that the main objective of the TerpNav system is to determine the most optimal walking path between two points that best suits the targeted audience's needs. The SEAM team members created a software program for TerpNav that calculates the shortest path between any two points.

The initial version of the program created by the SEAM team responsible for the outdoor component uses an application-programming interface to communicate with and draw the desired information from the OpenStreetMap database. Then, using an open source tool developed by the OpenStreetMap team called Osmosis, TerpNav parses the data and stores it on a local server on the University of Maryland campus in a database named "OSM-UMD." A utility program named osm2pgsql translates the data stored on OSM-UMD into data that can be read by a geographic information system (GIS) database. Then, the OpenStreetMap toolkit Mapnik takes the map data from the GIS database and renders the data as image tiles, on which mapping and route information is superimposed. The arrangement of tiles forms the actual map that the user sees in his or her browser. Due to a set of web development techniques known as "asynchronous JavaScript and XML," the map that the user sees in his or her browser can communicate with the aforementioned server so route calculation and other server-side processes can occur in real time and be presented to the user with little delay (SEAM, 2008).

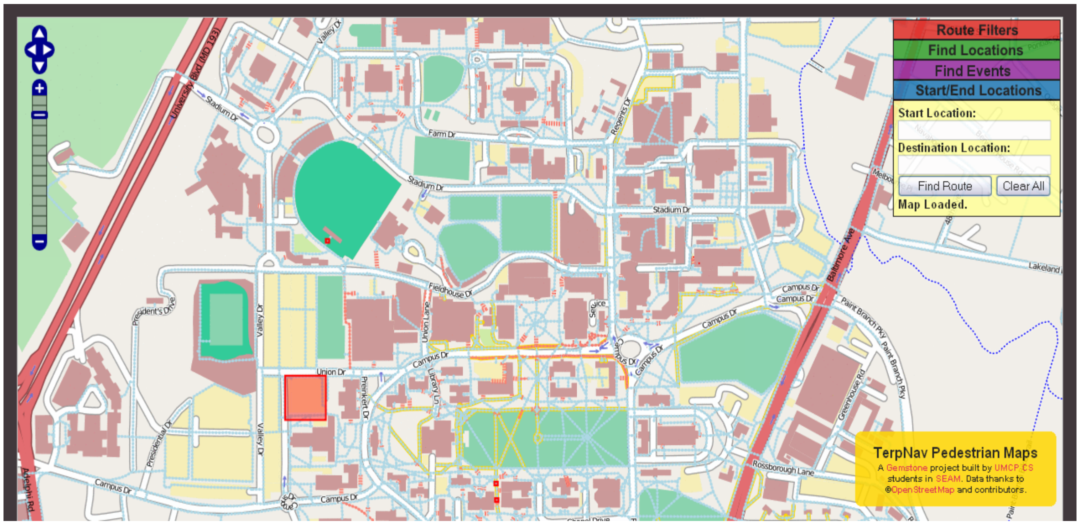
The flow of information in the design of TerpNav consists of three parts: the graphic user interface (GUI), the hypertext preprocessor (PHP) gateway, and the Ruby routing algorithm. The GUI collects necessary information from the user, including starting and ending points and options that filter out routes with steps, steep inclines, and no curb cuts. The PHP gateway converts the data from the GUI into an HTTP POST command that is sent to the server. The server then uses a path algorithm coded in the programming language Ruby to calculate the route, which is sent back via HTTP, processed by the PHP gateway, and displayed to the user on the GUI. For a diagram of TerpNav's flow of information, see Appendix E.

Basic Map Appearance

The map's user interface is based primarily off the OpenStreetMap interface, including the coloring of the map, its structures, and its symbols. The map appears as an overhead drawing of the campus, with buildings, fields, and parking lots represented as shapes and roads and paths shown as lines, some thicker than others (see Figure 1). Buildings appear as red shapes, shaped according to how they appear from above, and athletic facilities and green spaces appear as green shapes. All of the buildings and fields are labeled, although the labels only appear when the view zooms in completely, or when it almost zooms in completely for large buildings and fields. Roads appear as thick white lines outlined in black and labeled as appropriate. Highways, like Route 1 in the map of the University of Maryland College Park campus, appear as thick red lines with black outlines. Walking paths appear as blue dotted lines, with stairs marked by a series of short red lines and steep hills marked by red dotted lines. Blue-light phones, which can be used in case of emergency to contact the police, are also denoted on the map, as are bus stops and parking lots, including handicapped parking, indicated by the national handicapped parking symbol.

When accessing TerpNav through the Internet, the user initially sees the map zoomed out to show the majority of the campus, but has the option of zooming in further to see more detail or zooming out completely to view the entire world as it appears on openstreetmap.com. Users can move around the map using the arrows provided in the upper left-hand corner near the zooming feature, or by clicking on the map and moving the mouse in any direction. On the upper right-hand side of the map, the “Route Filters,” “Start/End Locations,” “Find Locations,” and “Find Events,” tabs provide interactive features for the user to optimize his or her navigation experience.

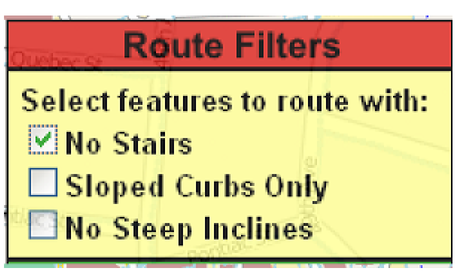
Figure 15: Basic Map Appearance of Phase One TerpNav Development



Route Filters

Because we wanted to include information regarding obstacles to pedestrian movement, specifically for the population of people using wheelchairs, the SEAM team also incorporated the concept of "route filters" into the navigation system. Using route filters, users can choose to avoid paths with certain obstacles such as stairs or steep inclines. The first phase of TerpNav contained three specific route filters: "No Stairs," "No Steep Inclines," and "Sloped Curbs Only," as shown in Figure 2.

Figure 16: Route Filters of Phase One TerpNav Development



To find the stairs present on campus, Team FASTR members, as well as SEAM team members, traversed the campus, noting areas where stairs were present. Although we had planned on evaluating steep inclines based on the "Americans with Disabilities Act and Architectural Barriers Act Accessibility Guidelines," we were not able to do so due to time constraints (U.S. Department of Justice, 1994). Instead, we approximated what we considered to be steep inclines for the initial development of the system. We identified the presence of sloped curb cuts through observation as well.

The three filters used in the first TerpNav development were chosen based on feedback from the interviews regarding what features were most important to include in a navigation system. The route filters are optional, and when used, return only the paths that satisfy the given filters. The filters are enabled by placing a check mark in the corresponding box. Once enabled, a new route between the two points is calculated based on the user's request. Having filters allows users to personalize their routes and receive the optimal path choice for their individual needs.

Start and End Locations

The SEAM team designed the system to give users two different options to set starting and ending points for the desired shortest path route. Users can either click on a location on the map and choose "Set Start" or "Set Stop," or input the location by typing it in a search box and setting it as the "Start Location" or "Destination Location" (see Figures 3 and 4).

Figure 17: Left-Click Menu of Phase One TerpNav Development

This menu below appears after clicking on the map. From this menu, one can set the "Start Location" or "Destination Location."

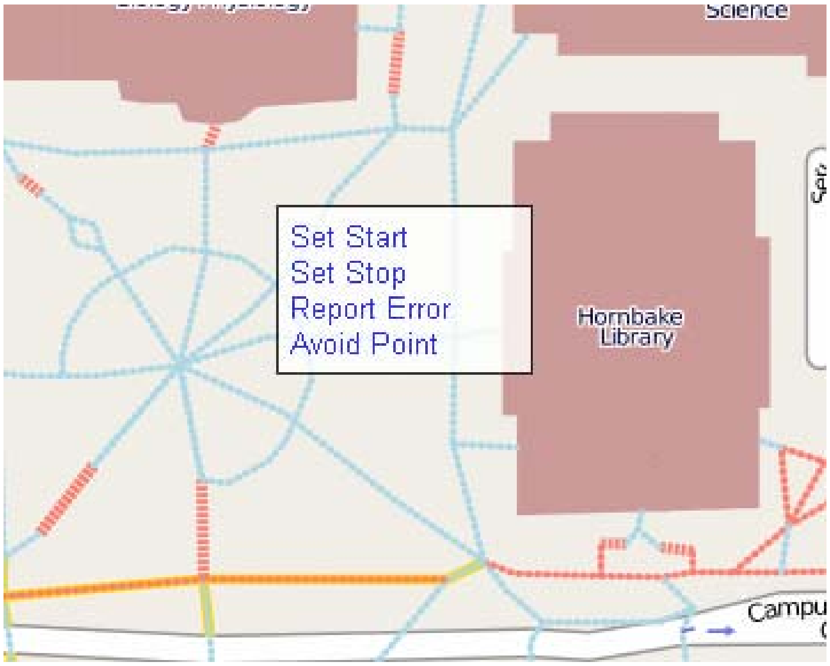
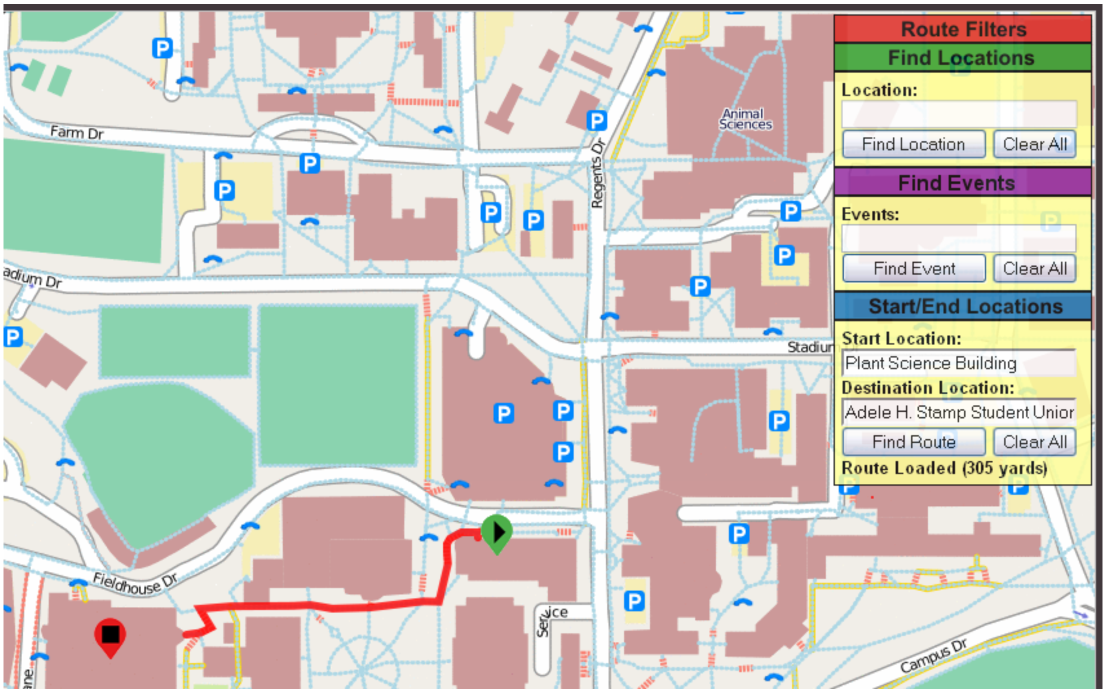


Figure 18: Search Box and "Start" and "End" Location Symbols of Phase One TerpNav Development

The figure below displays the placement of the search box for entering the "Start Location" as well as the "Destination Location." In addition, the "Start" and "End" locations are displayed.



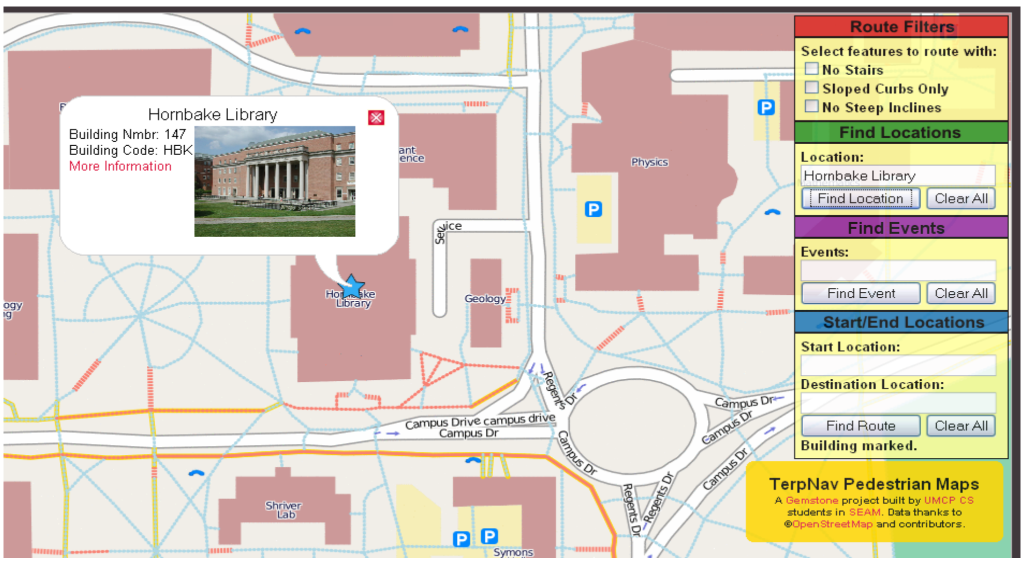
When using the search boxes, the names of locations on campus or their three-letter codes (assigned by the university) will begin to show up after typing in two letters. All of the names and codes with the letters or numbers typed in will appear in a list below the search box, with the option to click on one of the given options or continue typing.

Find Locations

Another feature available in the first development of TerpNav was the ability to search for a building or location on campus using the "Find Locations" search box (see Figure 5). The "Find Locations" search box functions in the same way that the

“Start Location” and “Destination Location” search boxes do. After inputting the name of a location on campus and choosing “Find Location,” a pop-up box will appear on the map itself with more information regarding the location, including a picture of the location, when available, and the location name and/or code, as designated by the university.

Figure 19: “Find Locations” Feature of Phase One TerpNav Development



Find Events

Events on campus were also searchable in TerpNav’s first development. After searching for an event by either typing in the name of the event completely or typing in a few letters and clicking on an event in the list of possible options that appears below, the title, location, time, and date of the event are displayed in a pop-up box on the event’s location on the map (see Figure 6). In some cases where a link has been provided to the event, the pop-up box will also contain a link to more information about the event. The route filter options, as well as the various search boxes described, are located in the top right-hand corner of the screen when accessing TerpNav.

Figure 20: “Find Events” Feature of Phase One TerpNav Development

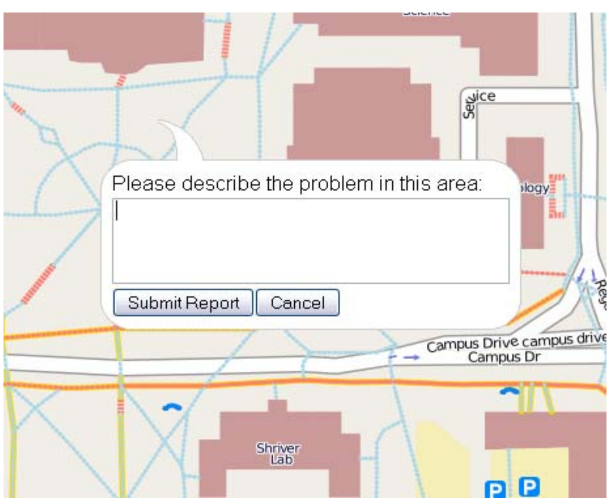
Sustainability Features

When we were initially designing the functionality of TerpNav, we intended to allow the community to make changes to the system data in an effort to establish TerpNav as a community-sustainable mapping initiative. The idea was that if a path on the map needed to be changed, due to temporary construction, permanent changes to the university, or other obstacles, users would be able to update the system instead of an administrator. The updates made by the users would affect the map in real time, potentially improving the lives of people using wheelchairs, who would be most affected by physical changes to the campus. However, we were not able to incorporate these specific sustainability features into the first phase of TerpNav, which required an administrator to make any additions or changes. During the first development, Team FASTR acted as the system's administrator. In addition, because some interview participants expressed hesitation in giving the community free access to update the map, we also wanted to further explore the issue of community sustainability in the user satisfaction survey to be completed after the first TerpNav development and rollout.

Report Error

Despite the inability to actually change map data, users were able to report errors they discovered on the map, using a "Report Error" feature. By clicking on the map and selecting "Report Error," users were able to type in a description of the error encountered and then submit it to the administrator (see Figure 7). During the development phase, Team FASTR monitored the errors reported and made the necessary changes. Although the first TerpNav development was not a truly community-sustainable navigation system, it did provide methods for user involvement with the "Report Error" feature.

Figure 21: "Report Error" Feature of Phase One TerpNav Development



Avoid Point and Global Avoid

Another sustainability feature included in the Phase One map was the “Avoid Point” feature, as well as the similar “Global Avoid” feature. The “Avoid Point” feature, available after clicking a point on the map, allows the user to create an area to be avoided when the system calculates the shortest routes (see Figure 8). However, the “Avoid Point” cannot be saved in this version of TerpNav and is only visible for a specific user during his or her use. The “Global Avoid” feature is available for all users, although it is controlled by an administrator. Areas under construction are indicated on the map in the form of translucent red boxes with dark red outlines delineating the construction and termed “Global Avoids” (see Figure 9). The administrator creates and updates “Global Avoids” based on errors reported and observation. When calculating a route, the system will avoid all of these “Global Avoids.” Although the “Global Avoids” cannot be updated by users, they are not permanent changes to the map, meaning they can account for temporary changes on campus. In addition, users can use the “Report Error” feature to report an area that should be a “Global Avoid” so that the administrator can update the map to make it more reliable.

Figure 22: "Avoid Point" Feature of Phase One TerpNav Development

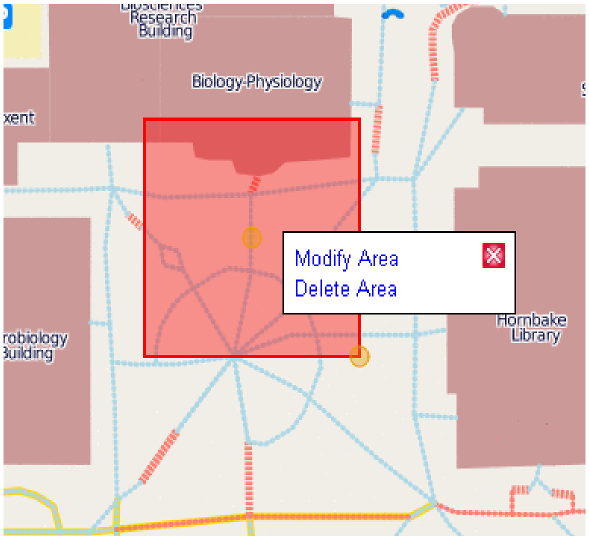
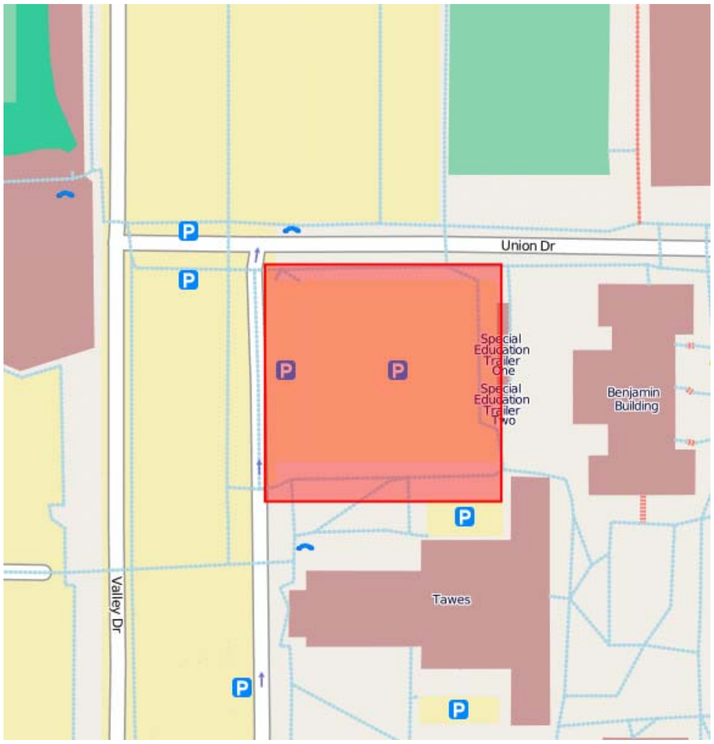


Figure 23: "Global Avoid" Feature of Phase One TerpNav Development



Events

In the first TerpNav development, the "Events" feature was also updated in a similar manner—only administrators had permission to add, remove, or change events, although the community could request events to be included in the system. Although the SEAM team did not have time to create a fully community-sustainable map that could be updated and changed by the users, some sustainability features were included to keep the map up-to-date. In addition, using OpenStreetMap, a community-sustainable map itself, as the map base enhanced the navigation system's sustainability.

Chapter 6: Rollout and Testing Phase

Method

Team FASTR launched the first prototype of TerpNav on the University of Maryland College Park campus in August 2008 at the URL www.map.umd.edu. Our goal was to launch it simultaneously with the start of the fall semester to target both new students getting to know the campus and returning students searching for the locations of their new classes. We assumed that the start of the semester would be the optimal time to launch the system, as it would attract the most users. Our hypothesis was that the system would have the most uses at the very start of a semester, when people new to campus, as well as returning students, would be looking for their new class and meeting locations. The launch of the system and the ensuing campus response are referred to as the "Rollout and Testing Phase."

Initial Data Check

Before rolling out our system, we first had to perform one last check for errors. During the summer of 2008, Team FASTR members walked around campus with printouts of the TerpNav's mapping data, noting the locations of stairs, steep hills, and curb cuts in order to update the data. In addition, we labeled handicapped-accessible building entrances, meaning ones without stairs or curbs, and blue-light phones, which can be used in emergencies. We performed as much data checking as possible before the actual rollout of the system at the beginning of the fall semester in 2008.

Advertising Campaign

In order to attract participation from the campus community, Team FASTR needed to advertise the TerpNav system. We began an advertising campaign that targeted University of Maryland students, faculty, and staff, as well as visitors to campus, starting while our system was still in the development stage and continuing until it was ready to be accessed and used by the entire campus in the fall of 2008. Our marketing tactics included attending popular campus-wide events, especially new student events; posting fliers in residence halls; e-mailing a variety of campus e-mail listservs; and assisting in the campus locator services by sponsoring two booths that displayed the TerpNav system during the first week of classes.

Campus-Wide Events

We attended Maryland Day, New Resident Orientation, the First Look Fair, and Family Weekend with the intention of promoting our new navigation system and with the assumption that events such as these would attract a large percentage of the student body. At each of these events, we handed out fliers that contained basic information about the TerpNav system, including the URL where it could be accessed.

Maryland Day, held each spring, is an opportunity for students, faculty, staff, and visitors to come to University of Maryland College Park campus to participate in events and observe presentations that highlight the university and its accomplishments. Many departments and programs have tables on the campus mall, the grassy area in the middle of campus, with activities and information regarding their programs. In the spring of 2008, we joined the Gemstone program's table and set up a computer to show people how our system works and to pass out fliers inviting them to visit the website on their own. Maryland Day was the first event at which we advertised TerpNav, where we intended to reach a large body of students, faculty, staff, and visitors.

We also attended events included in the New Resident Orientation in fall 2008 in order to target new students to the university. By handing out fliers and describing TerpNav, then at its final stages of its first development and ready for rollout, we were able to attract a large population of users from the freshman class, as our surveys later displayed. In addition, we also attended the First Look Fair, where students walk around booths that are set up on the campus mall to find out about the activities that are available on campus. We handed out fliers with the TerpNav URL at this event too, which also served to increase our user base.

Later in each fall semester, usually around mid October, the University of Maryland College Park campus hosts a Family Weekend with events, presentations, and performances for visiting family and friends of students. To continue to advertise TerpNav, we provided the Visitor Center with fliers to hand out at Family Weekend in order to attract visitors to the TerpNav system. Visitors are often unfamiliar with campus and we assumed that they would likely use some form of navigational assistance while on campus.

Fliers and Listservs

In addition to advertising at events, we also created fliers advertising TerpNav to be hung in residence halls around campus. These fliers remained in residence hall hallways for at least 2 weeks during the 2008 fall semester. In addition, we e-mailed a variety of campus listservs information about TerpNav to be posted in listserv e-mails that would go out to all students on a particular listserv. Because the listservs included department listservs as well as honors program listservs, we were able to reach a large portion of the student body. The fliers and listserv e-mails provided a quick, easy method of advertising TerpNav to the university community.

Campus Locator Services

During the first week of each fall semester, the university sets up several locator booths around campus to help students find their way to classes. In the fall of 2008, Team FASTR joined two of these booths on the University of Maryland College Park campus (one located in front of the Mitchell Building and one in front of the Stamp Student Union). At each of these two booths, we provided a computer to advertise how TerpNav worked and to enable students to look up locations. We also connected a printer to each computer so each student could print out an individualized route to take with him or her. Although we had some problems with the wireless internet connection on campus while located at the booths, TerpNav worked well for the most part, providing the quickest way for students to get to their classes. By using our system at the booths, we were able to locate the best path for individuals to take, as well as publicize TerpNav and create interest in the system.

Survey Preparation

To assess the level of satisfaction with TerpNav and to determine what additional features the campus community would like to see in future developments of TerpNav, we decided to administer a survey to TerpNav users. In preparing our survey, we determined that it was important to survey individuals who had actually explored the new system. Therefore, we added a splash page to the TerpNav website, www.map.umd.edu, that contained an explanation of how to use the system and a request for users to voluntarily enter their e-mail address in order to be contacted in the future about participating in a user satisfaction survey. Due to the variety of events we attended to promote our new system, we had many people sign up to use TerpNav, creating a large user base from which to gather survey participants. We also received feedback directly from many of the users who signed up for our system through the “Report Error” feature with which users could input comments that would be sent to an administrator. During TerpNav’s rollout, Team FASTR members served as the system administrator.

Results and Discussion

The first rollout of TerpNav provided useful data, both quantitative and qualitative, regarding both its successes and its weaknesses, to be improved on in the second development. For the errors reported by users, we will only consider the fall 2008 data. However, for all other data, we will consider the span of time beginning in August 2008 and ending in February 2009, right before the second rollout. Because we only advertised our system during the 2008 fall semester, we will be able to compare the usage data from the first semester, when we heavily advertised, to the data from the beginning of the second semester, when we did not actively advertise.

Errors Reported

As of November 1, 2008, 110 errors had been reported on TerpNav. Geographically, the errors spanned most of the campus, with a slightly larger concentration on South Campus. Examples of errors reported included: “There is a front door to Marie Mount Hall;" "No path from Tydings to Armory;" "This pathway behind McKeldin is very steep;" "Bizarre path from North of Stamp Union (Fieldhouse Drive) to front of BioPsych;" and "Connect the line going through the parking lot to the line going past Susquehanna." Although the text of the errors reported provides a qualitative assessment of TerpNav, displaying that there were sections of the map that needed updating, the "Report Error" feature also provided quantitative data.

The frequency of the errors reported and the nature of the errors themselves represented a quantitative measure of user satisfaction with our system. Compared to the number of users registered with the system, more than 1,000, and the number of times that the system was used, 20,832, the number of errors reported, 110, was small. Because most of the errors were comments regarding the paths on the map rather than the actual navigation system, we believe that people were actually thinking about the map as they were traversing campus, and then reporting the error after the fact, providing a positive outlook for the system's sustainability.

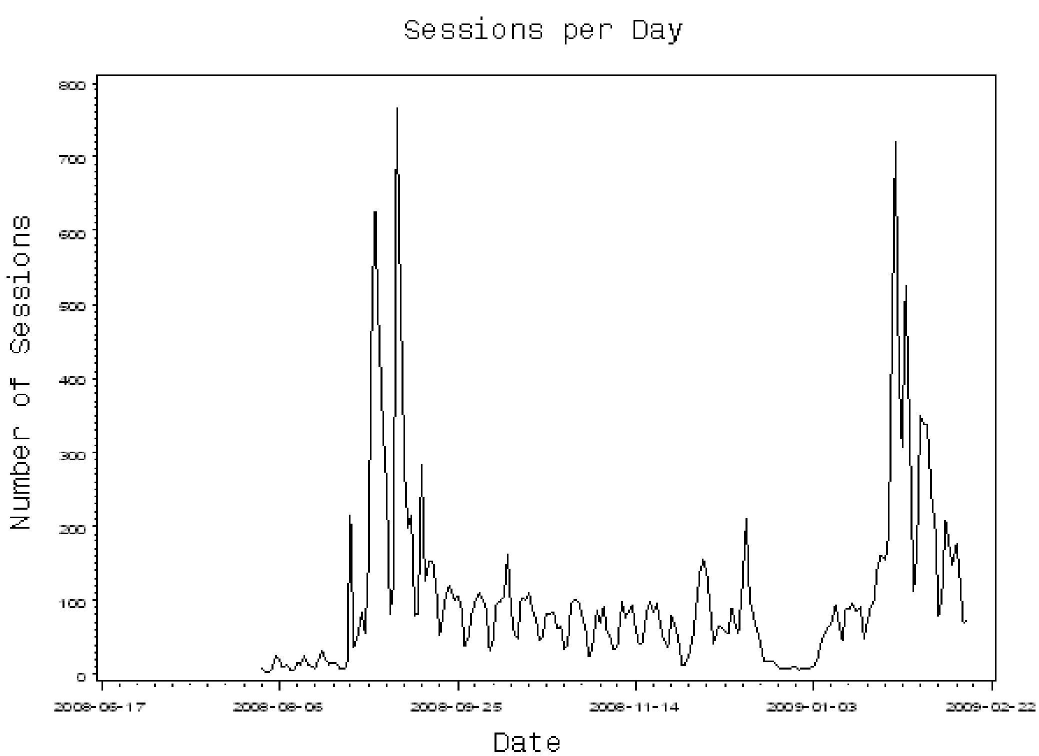
Usage Data

By looking at the number of usage sessions per day, meaning the number of times that TerpNav was accessed each day, over the span of several months, we were able to make some inferences about the use of the system. A session combines all of the actions that were taken by one Internet Protocol (IP) address when accessing TerpNav in a given 60-min period. In gathering the usage data, we assumed that there would be one person per IP address using the system in a given 60-min period. By having this assumption, we were able to combine the vast number of back-and-forth communications between a given IP address and the server into one “session.”

The total number of sessions between August 1, 2008 and February 15, 2009 was 20,832. Throughout the first 3 weeks of August 2008, the number of sessions per day was consistently lower than 35, but during the last week of August, the numbers rose to between 35 and 200. On the first day of classes, September 2, there were 627 sessions. As we hypothesized would occur, the usage frequency increased leading up to the first day of classes and spiked on the first day of fall semester classes (see Figure 10).

Figure 24: Phase One TerpNav Usage Graph

This figure displays the number of sessions that TerpNav recorded each day from June 17, 2008, to February 22, 2009.

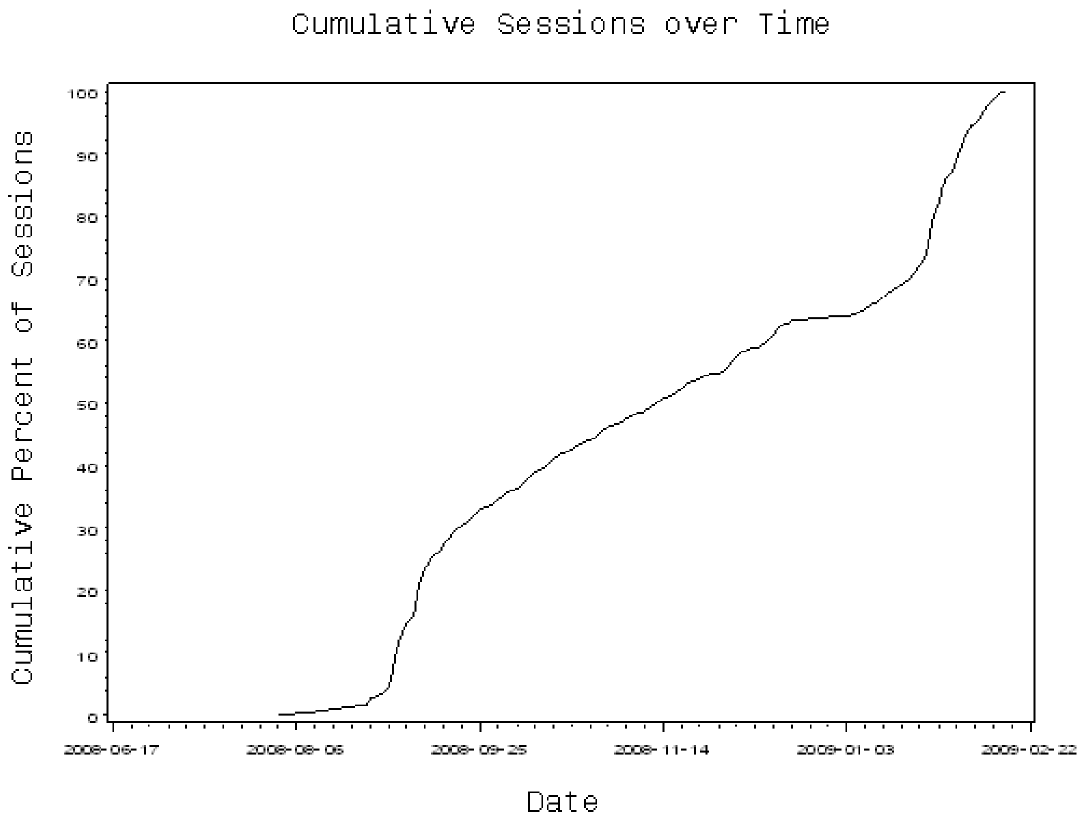


Although some of these sessions were due to our involvement at the locator booths on the first few days of classes, where we used our system to help students find their way around campus, our uses of the system would not completely account for such a large spike. We can conclude that many people used our system to find their classes at the beginning of the fall semester, confirming our hypothesis that this would be the most popular time to use the system. The usage numbers were somewhat lower for the rest of the fall semester (usually between 50 and 100), and dropped significantly at the end of December 2008, when most students left to go home for winter break.

However, there was another spike at the beginning of the second semester, totaling 720 sessions on January 26, 2009, the first day of classes of the spring semester. Given that we did not advertise or actively promote TerpNav at the beginning of the spring semester as we had in the fall semester, this suggests that people who learned about the system during the fall semester were satisfied with it and decided to use it to find their classes again during the spring semester. Also, although there could have been second-semester transfer students who were unfamiliar with the campus at the beginning of the spring semester, it is likely that many students who had been on campus for at least one semester still used the system to find their classes on the first day of the semester. Use of the first TerpNav development continued to increase gradually throughout the time it was available online, including spikes at the beginning of both the fall and spring semester (see Figure 11).

Figure 25: Phase One TerpNav Cumulative Usage Graph

This figure records the cumulative sessions over time, from June 17, 2008, to February 22, 2009. It displays that use of TerpNav continued to increase, with spikes at the beginning of both the fall and spring semester.

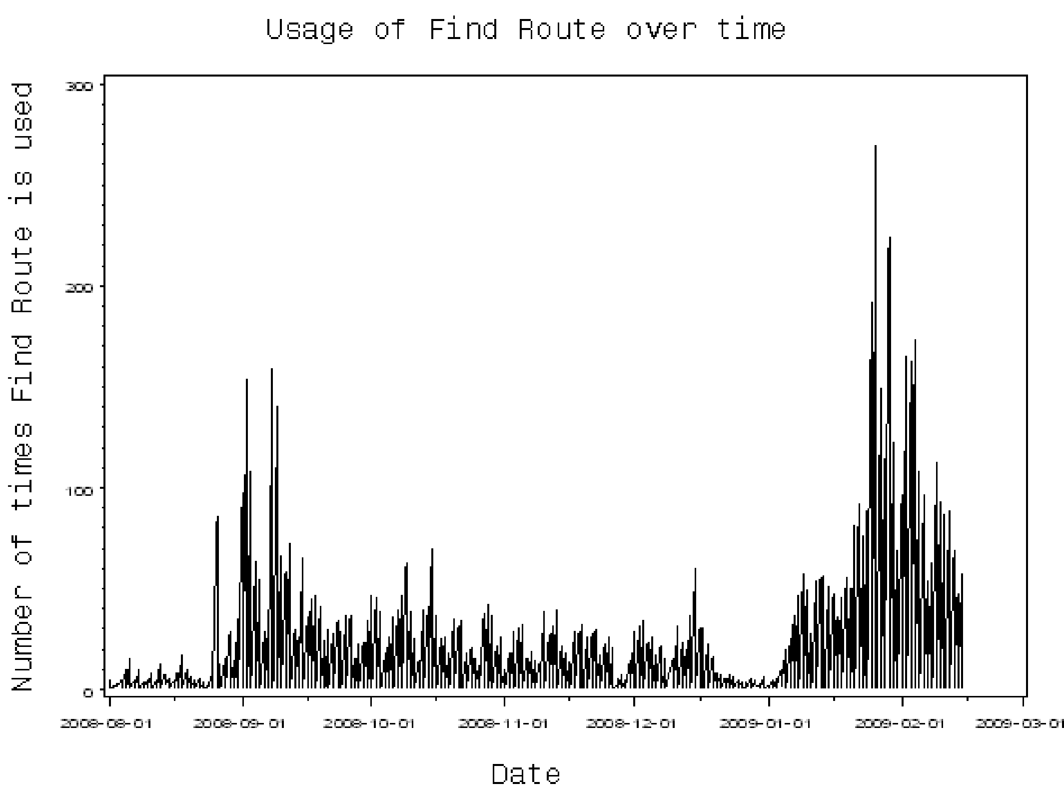


Overall, we can conclude that usage of TerpNav spiked during the beginning of the semester, both fall and spring, independent of advertising. These results help confirm our answer to the third research question, “What properties of the community-sustainable system will enable and attract participation by the community?” The features we chose to include in our system attracted participation from the community because the community continued to use TerpNav during the spring semester, even without advertising.

Through our usage data, we can also confirm which features were most popular among users. Based on the means for the number of times each feature was used per session, the most popular feature during our TerpNav rollout was the "Find Route" feature. The mean number of times that this feature was used per session was approximately 3.17, whereas the "Find Location" feature was used an average of approximately 0.21 times per session. By looking at the number of times that the "Find Route" feature was used per day, it also seems that this feature was used most often at the beginning of the semester, both fall and spring (see Figure 12).

Figure 26: Phase One TerpNav "Find Route" Usage Graph

This figure displays the number of times the "Find Route" feature was used per day, from August 1, 2008, to March 1, 2008.



In addition, this feature was used much more often at the beginning of the spring semester than at the beginning of the fall semester. The peak number of uses for the fall semester was approximately 160; the peak number for the spring semester was approximately 270 uses. These results could be due to the fact that almost 100 more people used the system at the beginning of the spring semester than at the beginning of the fall semester, displaying increased TerpNav use altogether. Supporting our selection of features designed to attract future community participation, these results imply that users were satisfied with the "Find Route" feature during the fall semester and returned to use not only the system, but also this specific feature, during the beginning of the spring semester.

Publicity

The campus as a whole provided strong positive feedback regarding TerpNav, with newspaper articles featured in both *The Diamondback*, the University of Maryland's independent student newspaper, and *Between the Columns*, an online university newsletter. *The Diamondback* article on TerpNav, "Speeding up the Campus Crawl," by Patsy Morrow, was printed on the front page of the September 8, 2008, issue (for a copy of the article, see Appendix F). Morrow (2008) stated, "While the map was made with wheelchair-users in mind, it has been a great tool to new students at the university." She also included quotes from students, such as: "'It was pretty useful,' freshman chemistry major Akshay Gandhi said. 'I knew where the basic buildings were like Stamp, but I didn't really know where a building like Martin Hall was, so it was really useful in figuring those things out'" (Morrow, 2008). In addition to quoting students, Morrow praised TerpNav herself:

> This is the first map of its kind at the university, and students are very appreciative of the services it offers because, unlike the university maps, "it has all the walking routes and not just streets," said freshman neurobiology and physiology major Theresa Chea. (Morrow, 2008)

The Diamondback quotes demonstrate the fact that students used TerpNav and were not only satisfied but very pleased with the system. In addition, given that Patsy Morrow's article was printed on the front page and did not include any negative feedback, it allowed for further positive publicity of TerpNav to the student body.

The article, "A Map Is Just a Map, Right?" written by Susan Warren, was posted on the *Between the Columns* website on July 2, 2008 (for a copy of the article, see Appendix F). In a quote to Warren, Douglas Duncan, the former Vice President of Administrative Affairs at the University of Maryland, said, "An updated campus map is an important step to take before a project to assess ways to reduce traffic on Route 1 can take place" (Warren, 2008). TerpNav not only has the potential to impact the community of people using wheelchairs, but also the entire campus community. The online atmosphere of this article allowed readers to comment, compelling one reader to post: "This is a great project. I think this idea should be expanded and improved for all students with disabilities, new visitors on campus, and also include small maps around the campus" (Gomez, 2008).

Sue Warren's article provided our project with exposure to the faculty and staff at the university. It also jump-started a positive working relationship between Team FASTR and the University of Maryland Visitor Center, which helped us get involved in more events and mapping initiatives on campus. For instance, without the help of Warren and the Visitor Center, we would not have been able to participate in the campus locator booths on the first few days of the 2008 fall semester. The support of Warren and the Visitor Center was instrumental in spreading the word about TerpNav and its capabilities, helping us to recruit a large user base for our survey.

Chapter 7: Survey

Method

A survey was administered to the community of TerpNav users in order to address the third research question: "What properties of the community-sustainable system will enable and attract participation by the community?" The survey was designed to evaluate the usability of the TerpNav system, additions or improvements desired by the population of users, and attitudes regarding the community-sustainability aspect of the navigation system.

Because our survey, like the interviews, included human participation, approval was needed by the Institutional Review Board (IRB). We obtained IRB approval in July 2008 to collect the e-mail addresses of people using the TerpNav system and to administer an online survey about their experience and satisfaction using the new mapping system. The survey was created using software provided by the University of Maryland Computer Science Department, a program named Terpvey that can be used both for survey design and data capture.

Participants

We selected participants for the survey based on who had used TerpNav. On TerpNav's homepage, www.map.umd.edu, users were given the opportunity to enter their e-mail address to be contacted in the future regarding participation in a user satisfaction survey. Giving one's e-mail address was entirely optional, as users could bypass this page to access TerpNav. Users who registered their e-mail addresses were contacted by e-mail approximately 2 weeks after registering and were invited to voluntarily complete the survey. The link to the online survey was provided in the e-mail. Participation in the survey was voluntary—both signing up to be given the chance to participate as well as deciding to participate. No other criteria were used to select participants; the objective was to poll a diverse group of people reflecting the demographics of the community as accurately as possible, although there is the possibility that our sample was not representative of the community as a whole. However, participation in the survey was available for anyone in the University of Maryland College Park campus community, including undergraduate students, graduate students, faculty, staff, and visitors.

Survey Interface

The survey was located on a webpage that is connected to and managed by the Terpvey software and the University of Maryland Computer Science Department. A login page containing a consent form and an outline of the objectives of the survey preceded the survey questions. Participants were required to enter an electronic signature, which included a first and last name as well as the date, in order to verify their agreement to participate in the study. As an additional option, participants were asked to provide an e-mail address to be entered into a raffle for one of six $50 Visa gift cards as appreciation for participating in our survey and supporting the TerpNav system. An individual's responses were kept separate from their identity as part of the confidentiality and anonymity agreement outlined in the IRB application, as well as in the consent form. The e-mail address provided as part of the survey was used solely for the purpose of the raffle.

Questions

Survey questions were divided into three main categories: use of the system, sustainability, and demographics, and were designed to address a range of topics. The section asking about the participant's use of the system consisted of questions regarding the participant's individual use of the system, including what features he or she had experimented with. This section also addressed user satisfaction with the current system, as well as recommendations for future changes to the system. The sustainability section of the survey first defined the term sustainability in the context of the TerpNav system and then addressed the potential motivation behind participation in a community-sustainable system, as well as a user's potential trust in a community-sustainable system. Because the first development of TerpNav was not completely community sustainable because it did not allow users to freely edit the data, this section of questions was referring to future development of TerpNav. The final section of the survey, concerning demographics, contained questions regarding the participant's' status at the university, his or her familiarity with campus, and any current navigational and transportation assistive devices used by the participant.

In total, the survey consisted of 33 questions: four single-answer multiple-choice questions, eight multiple-choice questions allowing unlimited response selection (i.e., "Check all that apply."), eleven Likert-scale questions, and nine open-ended free response questions (for a complete list of the survey questions, see Appendix G).

Multiple-choice questions were used when we wanted to identify specific answers from a participant, having his or her choose the best or most correct answer from a given set of answers. In some instances, only one choice could possibly be correct, as the answers were mutually exclusive; therefore, participants were allowed only one response. For example, one question asked for the participant's current status at the university, including such answers as "Undergraduate" or "Faculty," where only one option was possible. In other questions, a participant could potentially have multiple answers to a specific question; therefore, the option of choosing more than one answer was allowed. For example, one question asked what TerpNav features the participant used, where multiple options could be selected. In the survey, directions to choose "all that apply" were included. In multiple-answer multiple-choice questions such as this, a variety of answer combinations could potentially be chosen. In both styles of multiple-choice questions, the option to select "Other" was also provided to allow the participant the freedom to express another possibility that may not have been provided as an answer.

We also included Likert-scale questions in our survey, with our scale being from one to seven, one being the worst, "Not Satisfied" or "Very Unlikely," and seven being the best, "Very Satisfied" or "Very Likely." We used a Likert scale for questions intending to gauge the participant's attitude and feelings toward the question's topic. The participant chose a number reflecting just how strongly satisfied or dissatisfied her or she was with a particular feature of the system, or how unlikely or likely he or she was to use the system again.

Open-ended, free response questions were also included to allow the participant to provide the maximum amount of feedback, given that the participant could write whatever they wanted. Having this type of question provided the team with a variety of new ideas and a better understanding of the community's experience with the system. Example open-ended questions included in the survey concerned what additional features the user would like the system to include, as well as what problems they foresee with the community-sustainability aspect of the system. The responses from the open-ended portion of the survey were taken into account when modifying the TerpNav system for its second development. The open-ended portion of the survey allowed the team to gain additional insight into the satisfaction and attitudes of the campus community regarding the components of the TerpNav system.

Subjects were invited to participate in the survey by e-mail starting October 9, 2008, and the survey was available online until November 8, 2008. In this time period, 1,435 invitations to complete the survey were sent by e-mail, with a total of 524 survey responses. Two additional correspondence e-mails were sent after the initial invitation, reminding users to take part in the survey. The raffle occurred on November 12, 2008, and the winners of the gift certificates were notified through the e-mail address they provided.

Results and Discussion

As stated earlier, the survey was administered after the initial rollout of the system in order to answer the third research question: "What properties of the community-sustainable system will enable and attract participation by the community?" The respondents to the user satisfaction survey for the first version of TerpNav included students, faculty, staff, and visitors. As per the guidelines of the IRB at the University of Maryland, we removed the responses of all participants who indicated that they were under the age of 18 and all participants who indicated that they used the system zero times for the first question of the survey. Removing these data points left us with a total of 524 responses to the survey. The survey asked users about their general satisfaction with the system and its various features, their anticipated continued use of TerpNav, their estimated trust in potential community-sustainability features, and demographic information. Because the respondents to the survey are assumed to have used TerpNav, the word “respondent” and “user” will be used interchangeably. The statistical analyses performed on the data yielded results that were intuitive and expected, but important to the validation of our hypotheses on community-sustainable mapping. In addition, the qualitative data analysis performed on the open-ended questions produced confirmation of some of our initial hypotheses, as well as useful feedback for producing the second version of TerpNav.

Method of Analysis

After the survey period ended, we created variables that reflected the responses to particular questions. Variables cited in this section are described in the following table.

Table 1: Survey Variable Definitions

use_again	The respondent's self-estimated likelihood of reusing the system on a Likert scale (min = 1, max = 7)
features_use	The number of system features used by the respondent
communitysustainable_trust	The respondent's self-estimated level of trust in data received from a community-sustainable system on a Likert scale (min = 1, max = 7)
studentadmin_unpaid_trust	Indicator of whether respondent would trust an unpaid student administrator to manage the system
times_used	The number of times the respondent used the system
update_system	Indicator of whether respondent would update the system if the option was available
familiar_diff	The difference found when subtracting the respondent's self-estimated familiarity with the campus before using the map from the respondent's self-estimate after using the system

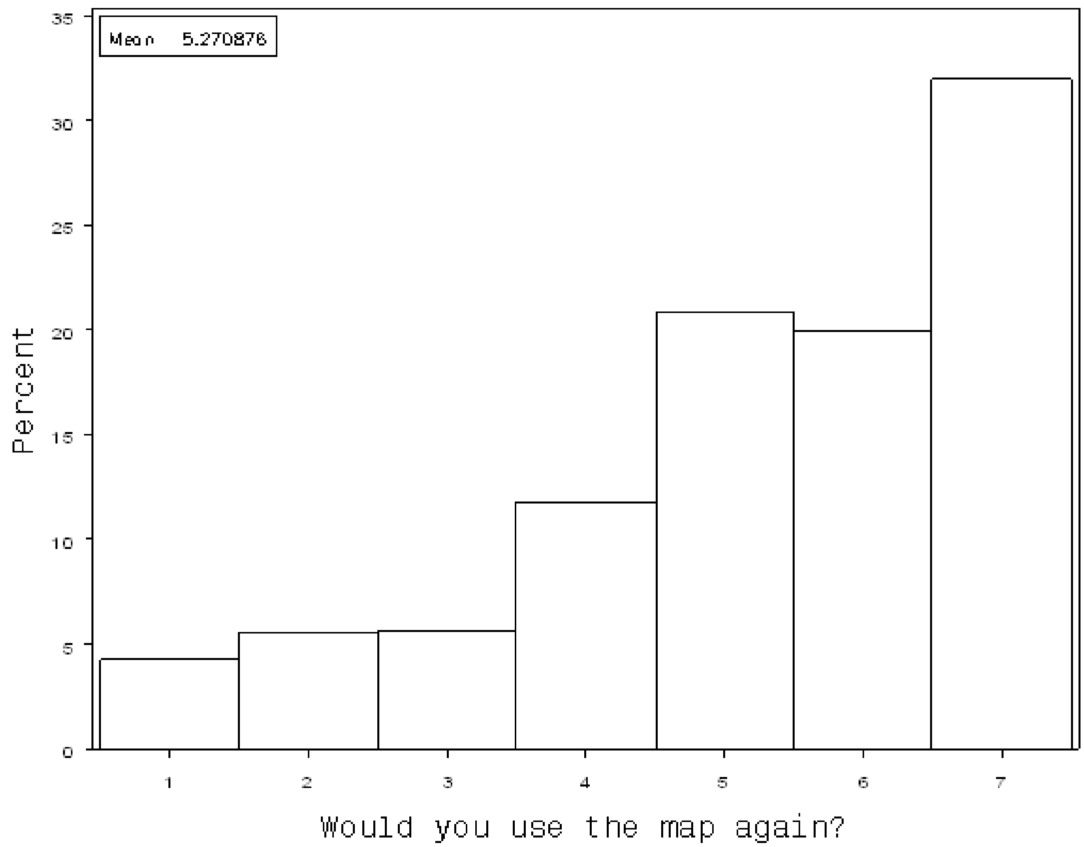
For the qualitative analysis, we coded all of the responses, grouping similar responses into categories and keeping a count of the number of responses in each category. Given that there was a mixture of quantitative and qualitative questions throughout the survey, we will explain the results using both the quantitative and qualitative analyses.

The Current System

Overall, we found that the respondents were generally satisfied with TerpNav. The variable use_again had a mean of 5.1189±1.7137. Although this value causes the hypothesis H_0: use_again ≥ 6 to fail, it still demonstrates the fact that the users were somewhat satisfied with the system (see Figure 13).

Figure 27: use_again Graph

This graph displays the percentage of responses for each number on the Likert scale, 1 being "Very Unlikely" and 7 being "Very Likely," answering the question, "What is the likelihood that you'll use the system again?"



We found that the correlation between the variables features_use and use_again was 0.18337, with a *p* value less than 0.0001, indicating a weakly positive, but statistically significant, correlation between the usage of features and the user's satisfaction with the system. This suggests that the more features the user tried out, the more impressed that user was with the system and shows that the features we decided to include in the system were found to be useful and practical by users.

In addition to asking about the user's satisfaction with the current system, we also asked about any problems that were encountered when using TerpNav. Although most of the problems were fixed during our initial testing of TerpNav, we assumed that given this was our first rollout of the system, there would be bugs. Seventy-three people (14% of the survey respondents) specifically stated that they had no problems with the system; 230 people, or 44% of the survey respondents, did not respond at all. Among those who reported having a problem, the most commonly cited problem (21%) was with the system freezing, when the system would stop responding. We believe this is due to the fact that the system is constantly pulling information from the server and, if the connection is interrupted for any reason, the system will freeze. Another common problem occurred in conjunction with the search function. Eighteen percent of the people who reported having a problem with the system claimed that the system did not recognize building names or numbers when they were typed in. This problem could be due to various reasons; possibly, the building names and/or all of the building aliases were not in the system—as it has to be typed in exactly as it is in the system—or it may have been due to freezing, as mentioned earlier. If the system froze while looking up a building name or number, it would not show up. Many of the specific building names that were not recognized have been added to the system's list of buildings since completion of the survey analysis. Zooming issues were reported by 4.5% of the respondents indicating problems, some who claimed that the zoom function went too far out and some who claimed that it did not zoom in enough. The responses to this question confirmed that there were bugs in the system when we released it, and emphasized the need to correct these bugs in future versions of TerpNav.

When asked a similar question regarding what problems users foresee with the system, survey participants gave very different answers. Four hundred thirty-four people (83% of the survey respondents) did not respond to this question. Of the people who did respond, 30% wrote that a future problem of the system would be its inability to keep up with campus changes, indicating to us that having an up-to-date navigation system was important to our survey participants. In addition, 6% of the respondents to this question stated that mistakes in the map could be a problem; however, this was less than 1% of our total survey respondents. These problems could also be alleviated by a sustainable system, one of our goals in the second phase of development. Other responses included problems with the portable device interface (7% of the question respondents), errors in building name recognition (10%), lack of a print option (2%), and not having the best route information and a time estimation option (13%). We tried to address all of these projected problems with our second development of TerpNav, which is discussed later in chapter 8.

Future Recommendations

In addition to asking users to foresee future problems with the system, we also asked them for recommendations for our second development of TerpNav. We asked survey participants which additional features they would like to see in a future version of the system. From our interviews and personal experiences on campus, we predicted that users would primarily be interested in security filters. In addition to the "No Stairs," "Sloped Curbs Only," and "No Steep Inclines" filters that were already present in our system, users not only recommended a security filter, but also a construction filter, a congestion filter, and a bike path filter, among other ideas. Seventy-five percent of the survey participants (391 people) did not respond to this question, but the responses we did receive were very helpful to our research. The most common additional feature cited (20% of the people who answered this question) was a security filter, one that would show well-lit paths with access to blue phones, or paths with the least crimes. Filters for construction and pedestrian congestion were the second-most common filter ideas (13% of the question respondents wanting each). Of the question respondents, 12% of the people mentioned having a bike path filter, although there was disagreement on what determines a bike path (bike racks, little congestion, safest road crossings, etc.). Seven and one half percent of the question respondents wanted an option to stay on sidewalks instead of having shortcuts through grass and parking lots, and 7.5% also wanted a filter to easily see the bus routes. Although the majority of survey participants did not respond to this question, the people who responded gave insightful answers regarding optional route filters and confirmed our hypothesis that a security filter is most desired.

Sustainability

Current System's Sustainability

Given that a large portion of our survey was dedicated to the proposed sustainability in a future development of the system, we first wanted to gauge user opinions regarding the current system's sustainability. Specifically, we asked, "Do you think that your use of the program will decrease over time?" to determine whether or not people would continue to use the system, and therefore, to have a stake in updating it to keep it reliable and accurate. The follow-up question asked "Why or why not?" and the responses indicated that most people believe that their use of the system would decrease due to getting acquainted with campus over time (78% of the people who responded to this question), something that would probably occur with any map of any campus. Of the 361 people who stated that their use of the system would decrease over time because they would become acquainted with the campus, 55 people (12% of the question respondents) specifically stated that overall use of the system would not decrease due to the continued presence of new students, visitors, buildings, and construction. Nine percent of the people who answered this question responded positively with this same reasoning, answering more for the entire campus' use of the system rather than their own personal use. Two and six-tenths percent of the people who responded also stated that they would be graduating and therefore not using the system in the future. Another 2.6% of the respondents did cite problems with the system as their reason for decreasing use, but this accounts for only 2% of our overall survey participants. For the most part, the reasons cited for having decreased use of the system were independent of the actual system; in addition, almost 100 people claimed that although individual use might decrease, overall use of the system would not. Although these results were not as positive as we would have hoped, for the most part, they did not represent a negative experience with the system.

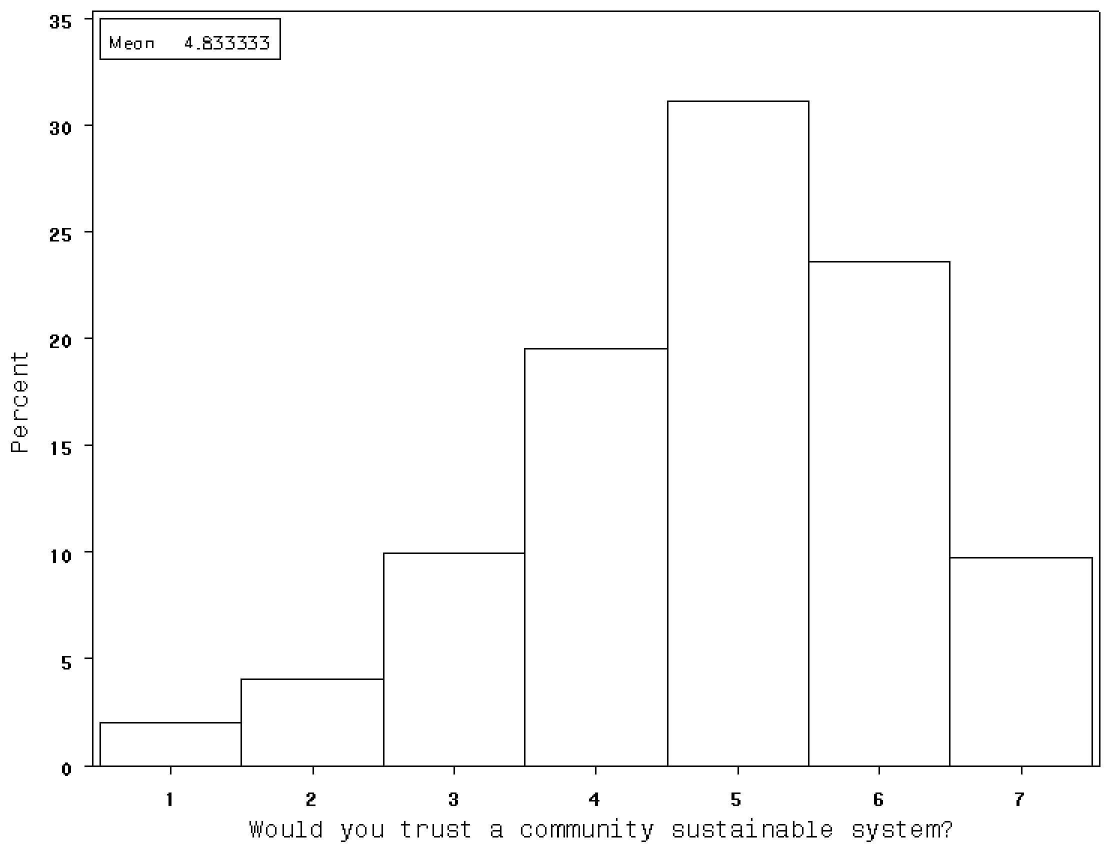
However, in order to try to increase the overall use of the system, we also asked survey participants what would attract their future use of the system. Fifty percent of the participants responded to this question. Similar to the responses to the last question, the most common response was unfamiliarity with campus (39% of the people who answered the question). Survey participants believed that the primary use of the system is based off of not being familiar with the campus, which is a common-sense concept. However, we also hypothesized that certain features of TerpNav would attract future use compared to other maps, and would continue to bring users back to our system even if they knew the campus well. Sixteen percent of the question respondents confirmed this hypothesis, stating that new features such as having more filters, being able to drag routes and/or personalize use of the map would attract future use of TerpNav. In addition, 10% of the people answering this question believed that making TerpNav more user friendly, including better graphics, increased reliability, and simplifying the search function, would increase the use of the system. Nine percent of the question respondents claimed that having time and distance estimations for routes would increase future use of the system, a result that directly led to a modification in the system for the second phase of development. Advertising and having a link off of the University of Maryland website was also cited by 8% of the respondents as a feature that would increase future use of the system. After the survey was completed, we were able to get a direct link from the University of Maryland homepage on a listing of three total campus maps. User recommendations for attracting future use of the system confirmed some of our hypotheses and provided new ideas that we had not previously thought of that were very influential in the second development of TerpNav.

Future Community-Sustainable System's Potential

The survey results also provided important findings related to the concept of a fully community-sustainable system. We wanted to know what it would take for the users of TerpNav to trust a fully community-sustainable version of the system. The stepwise variable selection method for determining regressions shows that communitysustainable_trust is modeled by the variables update_system, times_used, and studentadmin_unpaid_trust, variables that are all related to trust and participation in TerpNav. We found that users who wanted the map updated for others' future use also would trust all registered users to update the system. This indicates the potential for a successful community-sustainable system when there is goodwill and trust among system users. We found that people who would not trust a community-sustainable system wanted to have an administrator responsible for updates and changes to the map. Conversely, people who would trust a community-sustainable system did not want to have an administrator. These results are consistent with what would be expected. However, the variable communitysustainable_trust had a mean of 4.833±1.373, which is slightly greater than the median choice of 4 (see Figure 14), suggesting that most people would trust a community-sustainable system.

Figure 28: communitysustainable_trust Graph

This graph displays the percentage of responses for each number on the Likert scale, 1 being "Not at all" and 7 being "Very," answering the question, "Would you trust a community-sustainable system?"



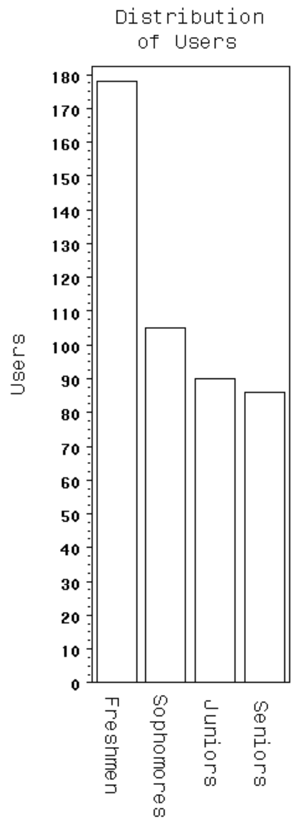
Another aspect of community sustainability that interested our team was whether users would be willing to contribute to such a system. We found that according to the variable update_system, 58.4% of the respondents stated that they would update the system. This indicates that more than half of the respondents to the survey would be willing to contribute to a community-sustainable system. We also found that the correlation between update_system and the number of semesters was 0.1374, with a *p* value of 0.0032, which indicates with statistical significance that people who have been on campus longer would be slightly more likely to update the map if they could. This result makes sense given that people who have spent more time on campus and have become more familiar with it would be more confident in contributing to a campus map.

Demographics

The third category of results includes the responses to demographic questions. The ages of the survey participants ranged from 18 to 66, with the majority of respondents (60%) being between 18 and 20 years old. The largest age group of survey participants was 18-year-olds (29% of the respondents). As would be expected from a survey about a system that aids visitors and new students, freshmen were the largest student group to take our survey (see Figure 15).

Figure 29: Users by Year Graph

This graph displays the distribution of students who took our survey, by year. People who have been on campus for more than 4 years are omitted.



In addition, 95.54% of respondents indicated that they used TerpNav on their personal computer. This result is important because implementing TerpNav to be usable on platforms other than the personal computer is a future goal. This also implies that users were able to plan routes in advance on their own computers before attempting them.

We also found results that reflected the users' expected familiarity and knowledge of the campus. First, more upperclassmen, faculty, and staff used the report error feature. Underclassmen, who are less familiar with campus, are probably less likely to find an error in the map. Freshman undergraduate students accounted for the largest group of users, which suggests that more freshmen needed to use the system to locate buildings and find routes than other users. We found that freshmen became more familiar with the campus because of their use of TerpNav. The mean of familiar_diff for respondents who indicated being on campus for only a semester was 2.335±1.284. This increase in knowledge of the campus was not observed among students in later years, as we found the correlation between year and familiar_diff was –0.58895, with a p value less than 0.0001. We also found that the correlation between the variables year and use_again was 0.3591, with a p value less than 0.0001. Students who had been at the university for less time learned more about the campus by using TerpNav than did students who had been on campus longer, and stated that they were more likely to use TerpNav again. This supports our hypothesis that freshmen will be the largest group of TerpNav users.

Limitations

There were some limitations with the results of the survey given that the set of respondents was incomplete in some ways. No respondent indicated that he or she used a wheelchair. Because one of the purposes of TerpNav was to make accessibility information more readily available, the lack of input from people who use wheelchairs was disappointing. We also had very few visitor respondents to the survey. It would have been interesting to see if visitors reacted differently to the systemthan people who were already familiar with the campus. Lastly, only 17 respondents indicated that they used the "Report Error" feature, which was one of the main components of community sustainability in the first version of TerpNav. With so few people having actually used the sustainable aspect of the system, we could only draw conclusions from the respondents' self-estimated valuations of the idea of community sustainability. Additionally, the fact that we removed all responses by people who were under 18 years of age may have skewed the survey responses.

Survey Conclusions

The survey results yielded several important conclusions concerning the success of the first TerpNav prototype and the idea of community sustainability. First, users were generally satisfied with the system. Second, users showed interest in a community-sustainable system as indicated by their self-estimated trust in such a system and their likelihood to participate in updating the map. Third, the users who benefited the most from TerpNav were freshman undergraduate students. Other questions that might be useful to ask in the future include what kind of model would best fit the number of active users of the system as it changes with time; whether enough people would use the system and its sustainable features for it to be useful; and if the addition of new filters, such as a security filter or a bike path filter, would increase the number of users of the system. Ideally, there would be many iterations of TerpNav that would eventually include these features; with our time constraints, we were able to complete a second phase, discussed in the next chapter.

Chapter 8: Phase Two Design and Development Process

Method

Based on the results of the first rollout, including the reported errors and the survey responses, as well as observations from the team members, Team FASTR contracted three more Software Engineering at Maryland (SEAM) teams to work on improving TerpNav in the fall of 2008. We first created a comprehensive list of desired improvements. Then, we narrowed down the list to the most important changes that could be accomplished within the given timeframe—one semester. Just as before, we transformed our priorities into specific design features by creating example screenshots of how the changes would appear with specific descriptions of how each new component of the system would function (for examples of these screenshots, see Appendix H). Our priorities were divided among three SEAM teams, one working mostly on making TerpNav Personal Digital Assistant (PDA)-compatible; another working on improving the basic components of the TerpNav program; and another focused on adding new features to the system, specifically, sustainability features.

Continuing to work toward the goal of having a community-sustainable navigation system, we first wanted users to be able to add notes to the map that would be available for anyone to read. Second, we wanted to expand on the "Events" feature so that any user would be able to add an event. Third, we wanted to keep the "Report Error" feature from the first phase of TerpNav, but we wanted any user to be able to see these errors. Finally, we wanted to have separate "wiki" pages for buildings, events, and notes. The SEAM team working on the sustainability features was given all of these requirements before beginning their work. The other two teams operated mostly on their own, with little input from us.

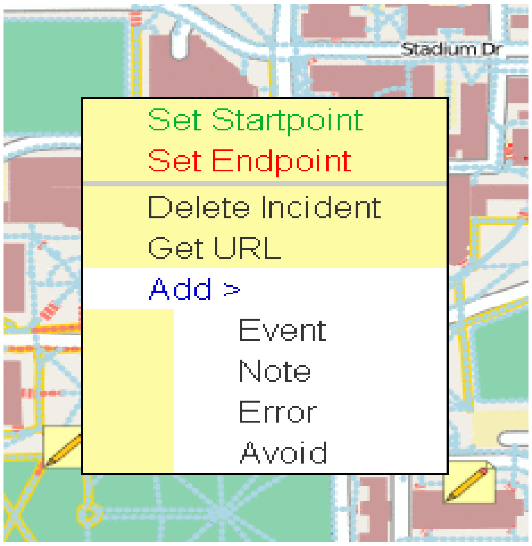
Results and Discussion

The SEAM teams completed as many of these changes as they could, given time constraints. Although all of the SEAM teams had some success, the most important outcome was the second version of TerpNav, which was developed by the SEAM team working on additional sustainability features. The second version of the map has more features than the first version while still maintaining the first TerpNav development's features, although the presentation is somewhat different. Because much of the second TerpNav development is the same as the first, we will only describe the differences between the first and second TerpNav phases.

Menu Options

In the second version of TerpNav, users can right-click on the map to bring up a menu of choices. Instead of the "Set Start," "Set Stop," "Avoid Point," and "Report Error" options that the first TerpNav development contained, the new menu has "Set Startpoint," "Set Endpoint," "Delete Incident," "Get URL," and "Add…" options (see Figure 16). Under the "Add…" option, there are also additional options to add an event, note, error, or avoid, each of which is associated with that location on the map.

Figure 30: Menu Options of Phase Two TerpNav Development



Sustainability Features

Add…

The "Add…" feature creates more community sustainability within the second TerpNav development, providing users with more options to edit and update the map themselves. For instance, in this version of TerpNav, users, not just administrators, are able to add events. When adding an event, users can include a name, date, time, and description of the event, just as an administrator could in the first development of TerpNav.

When users click on the location of an event after it has been added, a pop-up is displayed with the name, picture, and link to the website of the location, as well as a list of events or errors for that location (see Figure 17). There is also a link to a page that contains details about the event or error. These details are put in by the user who created the event, and can include the name of the event, a description, and a date and time (see Figure 18).

Figure 31: “Event” Feature 1 of Phase Two TerpNav Development

This figure displays the pop-up that appears after clicking on the “Event” symbol, a blue star.

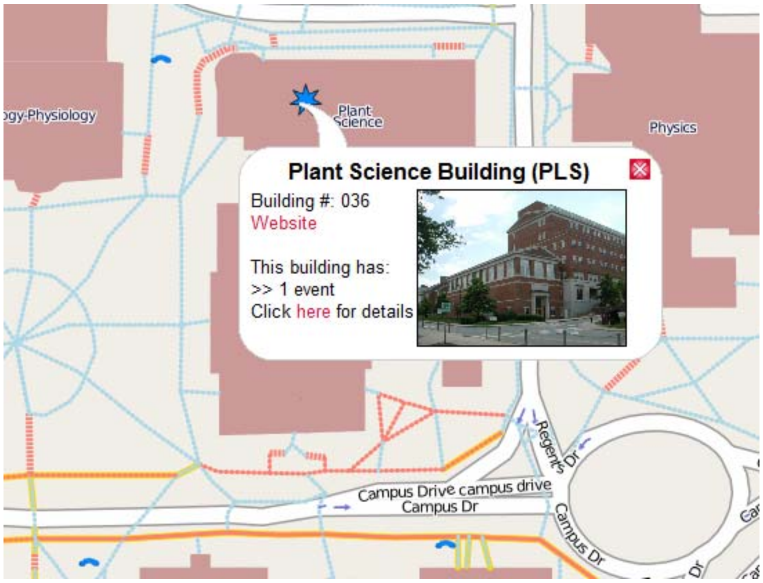
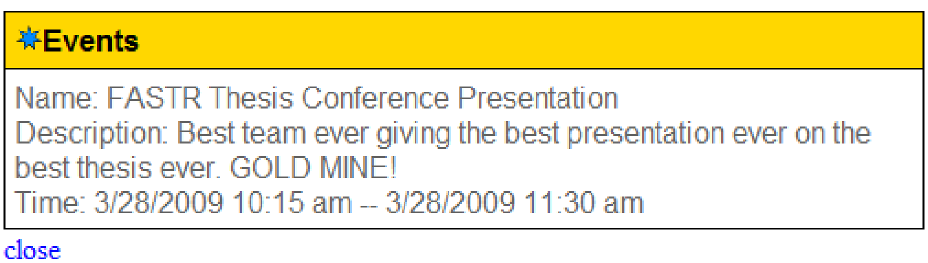


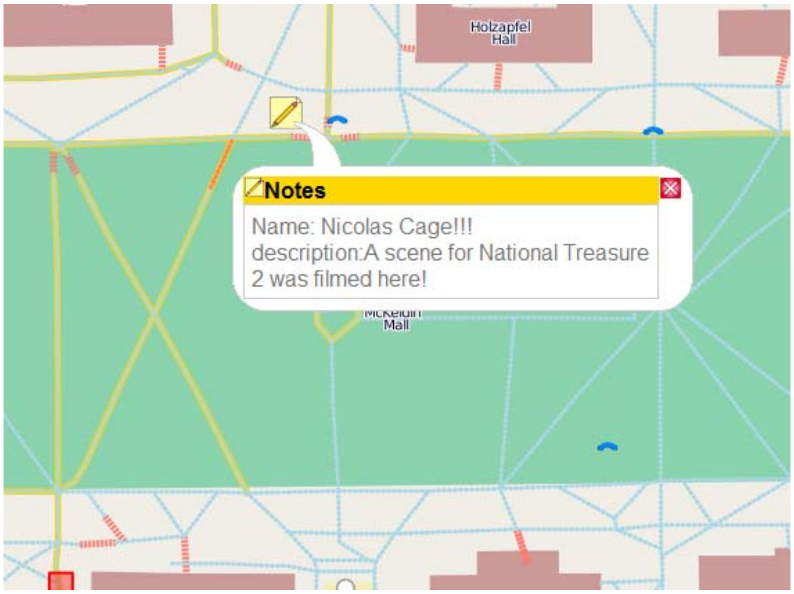
Figure 32: “Event” Feature 2 of Phase Two TerpNav Development

This figure displays the webpage that shows up after clicking on the link from an “Event” pop-up.



Users are also able to add notes and errors to the map, which can be seen by all users. As an example, a note could be placed on the University of Maryland’s mall area to say, “A scene for National Treasure 2 was filmed here” (see Figure 19).

Figure 33: “Note” Feature of Phase Two TerpNav Development



Although this is just a fun example, notes can also serve informational purposes as well; for example, a user could note what departments are located in a building. When users add notes or errors, they may include a title and the note or error itself.

In addition, users can add an “Avoid Point,” which is a square of variable size, to areas that cannot be navigated for any reason, including construction, a temporary event, and other. The system will then avoid this area when giving the shortest route. The “Add…” feature provides much more functionality to the user, and the ability to sustain the system, than what was offered in the first development of TerpNav.

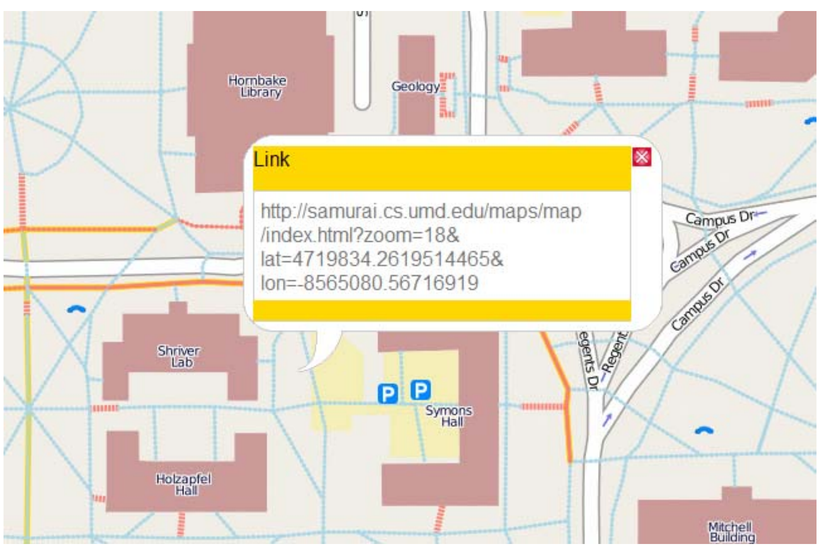
Delete Incident

The “Delete Incident” feature can be used to delete notes, errors, and avoids. This feature maintains the accuracy of the map, as users can delete a note, error, or avoid area that is incorrect or that has since become unnecessary to include on the map. Like the "Add…" feature, this feature adds to TerpNav's community sustainability.

Get URL

The "Get URL" feature provides a pop-up window with a static link for that particular location on the map (see Figure 20). When the link is pasted into a new browser window, the map with a balloon on that location appears. This feature could be used to e-mail visitors a meeting point instead of telling them the name of the building or location and having them find it on a map on their own. This feature adds to the functionality of the system, allowing users to personalize their mapping experience and get the most benefit from TerpNav.

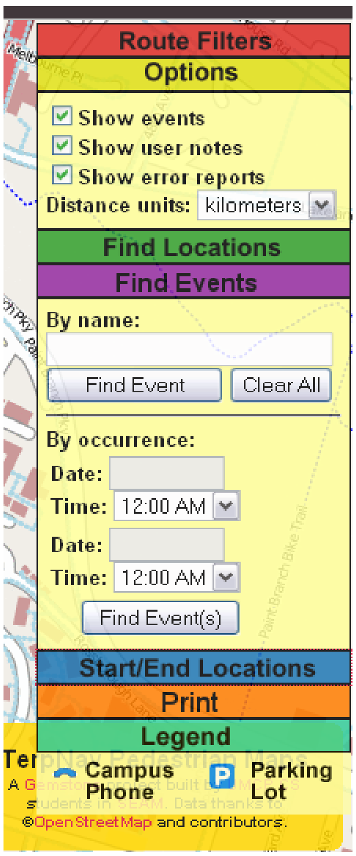
Figure 34: "Get URL" Feature of Phase Two TerpNav Development



New Tabs

Figure 21 exhibits the new tabs that are offered in Phase Two of TerpNav development. These tabs appear in the upper right-hand corner of the screen when accessing TerpNav.

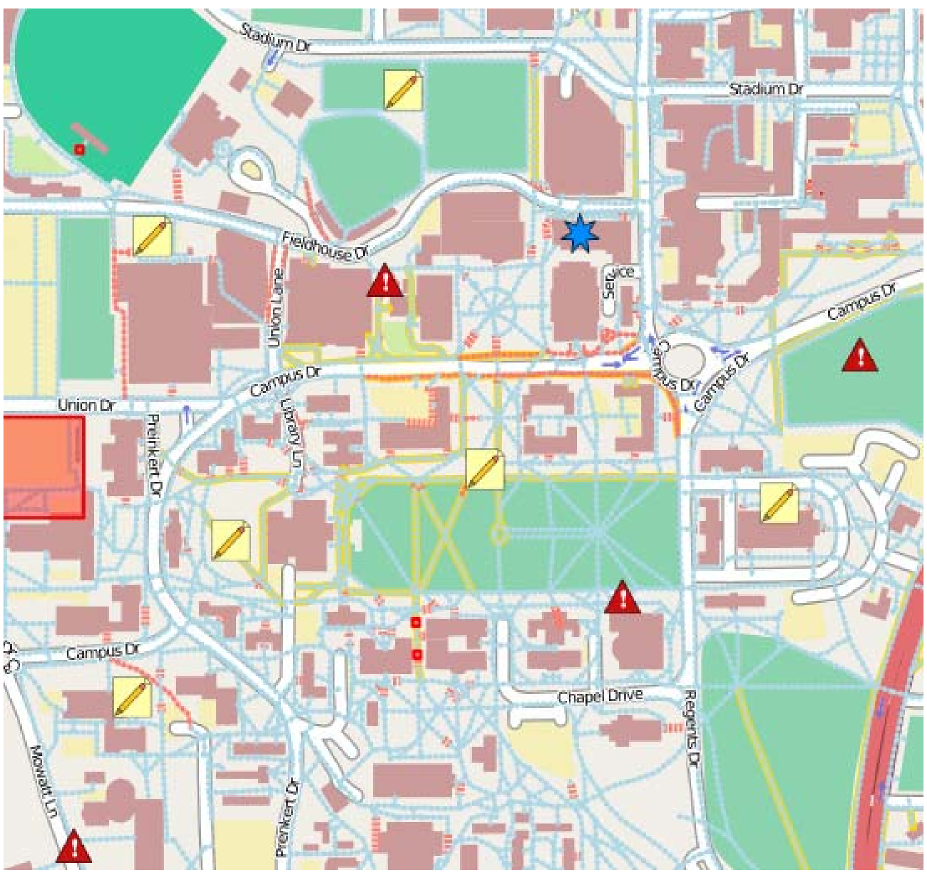
Figure 35: New Tabs of Phase Two TerpNav Development



Options

For the Phase Two TerpNav development, several tabs were added to the list of tabs on the upper right-hand side of the screen, including a tab for "Options." This tab provides an option to display distance units in yards, feet, miles, meters, or kilometers. Users may also check boxes to show events, user notes, or error reports, depending on what they want to be visible on the map. Events are displayed on the map as blue star icons, notes are displayed as yellow squares with a pencil, and error reports are displayed as red triangles with an exclamation point (see Figure 22). By having these filters available, users do not have to look at a map cluttered with different icons if they are not interested in events, notes, or errors. These aspects will only show up when the check boxes are enabled.

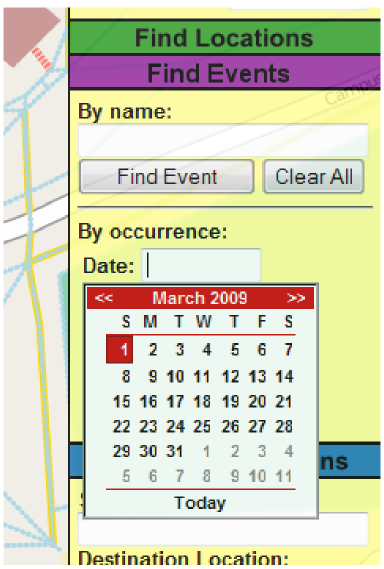
Figure 36: New Options of Phase Two TerpNav Development



Find Events

The "Find Events" tab was also updated in the second TerpNav development. Using this tab, users can search for events by name, as before, or by occurrence, by choosing start and end dates and times. For instance, if a user wants to know what events are happening the following day, he or she can click in the "Date" box and a small monthly calendar will pop up, where the user can pick a specific date to search for events (see Figure 23).

Figure 37: "Find Events" Tab of Phase Two TerpNav Development



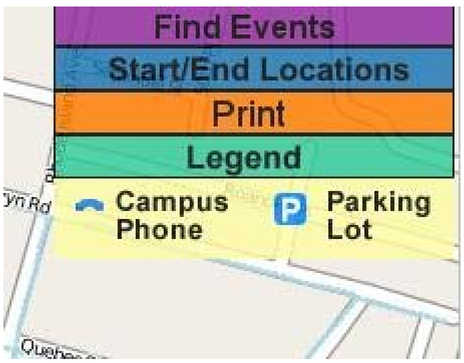
Print

The second phase TerpNav prototype also features a "Print" tab as a result of feedback from users requesting this feature (see Figure 24). When the user clicks on "Print," the current view of the map, including any route displayed on the map, will be printed.

Legend

The “Legend” tab, which can be updated by the administrator, contains a legend of symbols on the map. It currently shows the symbols for Campus Phones and Parking Lots (see Figure 24).

Figure 38: “Print” and “Legend” Tabs of Phase Two TerpNav Development



Phase Two Conclusions

As mentioned in the sustainability section of our literature review, localized information such as events and notes changes more rapidly than structural information such as buildings, meaning that sustainable systems are useful in showing changes in localized information. Therefore, in order to make the second development of TerpNav more sustainable than the first, we added features to allow users to change localized information. These new features also provide more opportunities for users to interact with the map, and many of these interactions are visible to the rest of the community of users. Although both the old and new mapping systems have been available for comparison and system testing, we have not yet formally launched the new TerpNav to the university community at large. If upon rollout we find that people use these new features with increased frequency, then this would further support our conclusion that people are willing to actively participate in making the map better, and from this, we would be able to infer that people would also be willing to update the map if they had the ability to change more features, including pathways and obstacles to pathways such as stairs and steep hills. Despite the lack of statistically testing and analyzing the results from the second development of TerpNav, we were still able to produce a prototype that built on the lessons learned and feedback from the first prototype and therefore, brought us another step closer to our ultimate goal of a community-sustainable navigation system.

Chapter 9: Discussion

The research and analysis that were conducted by Team FASTR have implications on both a local and global level. The local implications affect the community at the College Park campus of the University of Maryland. The global implications have potentially broader societal effects on communities beyond the university.

Local Implications

Team FASTR commissioned and designed TerpNav, a community-sustainable navigation system, with a specific focus to address the navigational needs of people who use wheelchairs; however, TerpNav is available to the entire campus community of students, faculty, staff, and visitors, regardless of their navigational ability. The system's ability to display a route between locations on campus and to show locations and points of interest work equally well for people who use wheelchairs and people who do not. Thus, TerpNav has the ability to fit the needs of the entire campus community.

We believe that TerpNav can be a beneficial application for the University of Maryland College Park campus community. First, TerpNav provides the framework for establishing a sense of community within the campus. Our research demonstrates that TerpNav provides users with an increased knowledge of the paths, building locations, and points of interest on the university campus. User-editable events and notes are features that have been implemented in the second iteration of TerpNav, which is aimed at increasing user participation as a forum for campus community events to be promoted.

As proof of its benefits to the university campus, TerpNav was selected for use by the University of Maryland Visitor Center to display the fastest route between two points and points of interest on campus to people visiting the university. TerpNav is also featured on the university's main webpage (www.umd.edu, under the tab "Campus Maps") and on the webpages of several university departments and offices, such as the Office of Information Technology Help Desk (www.helpdesk.umd.edu, under "Campus Location Information"). For additional Team FASTR and TerpNav achievements, see Appendix A.

TerpNav can also be useful to the University of Maryland Facilities Management Department. For instance, in a use-case scenario, if an automatic door is not working properly and a person using a wheelchair realizes this malfunction, the individual could report the malfunction in the system to be immediately sent to the appropriate Facilities Management staff so that the repair could be made in a timely fashion. This functionality would be very beneficial for all users, not just people with mobility concerns.

As suggested in the interview responses, TerpNav will also add to the attractiveness of the university, especially for people to whom navigation and mobility are daily concerns. Although the university already attempts to create accommodations for people with disabilities, TerpNav goes a step further, enabling the distribution of navigation information for people with mobility concerns. Finally, TerpNav is a product of the effort and ingenuity of University of Maryland faculty, staff, and students. It can serve as both a promotional item for the University of Maryland and the grounds for future university research and development.

Global Implications

Beyond the realm of the University of Maryland, the research that Team FASTR has conducted makes an impact on a global level. Although common online mapping services such as MapQuest, Google Maps, and Yahoo! Maps cover large swaths of the globe with vehicle navigation, they have only recently begun to apply their technologies to pedestrian navigation. Community-sustainable pedestrian navigation systems are needed to fill in the gaps of navigation data for the thousands of cities and enclosed campuses in which billions of people use pedestrian-only paths for travel. In addition, people who use wheelchairs can benefit from specialized travel data with responsiveness to change in any environment. In this sense, TerpNav's functionality can have great implications in the global world of mapping technology, and future research should study these implications. For instance, we are assuming that our research can be applied to other pedestrian-based areas, but we hope that other researchers will continue to study this subject to determine the extent of these possible applications. Our hope is that this research would further validate the global implications of our study.

As stated earlier in the paper, TerpNav uses OpenStreetMap as its source of community-sustainable navigation information. OpenStreetMap allows anybody to add or edit geographic mapping information after creating an account. All of the buildings, roads, paths, and fields on the University of Maryland College Park campus that are displayed in TerpNav were manually added to the OpenStreetMap database by involved individuals. According to our software logs, during a 2-1/2-month time period, 11 separate users made edits to the University of Maryland campus area in OpenStreetMap, impacting TerpNav's geographic data. These individuals included, but were not limited to, the members of Team FASTR and the collaborating Software Engineering at Maryland (SEAM) teams. The method of applying the geographic information extracted from a community-sustainable geographic information system can be applied on a global scale. The OpenStreetMap database has now grown to cover most of the United States and the United Kingdom. In addition, our survey results show that people who used TerpNav were generally pleased with it and would use it again, suggesting that a map based off of information obtained in a sustainable manner can be useful and popular, which helps to further validate sustainable navigation systems.

Limitations of Our Research Study

The first limitation of this study is the limited availability of people who use wheelchairs on the University of Maryland College Park campus. We were not permitted to obtain a definitive number of how many students at the university use wheelchairs, and we were not allowed to have direct access to their contact information. With the help of the staff at the Disability Support Service, however, we were very fortunate to have received the input of six individuals during the interview portion of our research process; but, according to our survey results, no eligible persons who use wheelchairs participated in our survey following implementation of TerpNav. The limited participation of people who use wheelchairs limited the amount of information we were able to receive and analyze in order to address the needs of people using wheelchairs and evaluate the usefulness of the accessibility features implemented in TerpNav.

The second limitation of this research study is the availability of resources and time to implement all of the ideas that we had regarding the research process and TerpNav's functionality. The SEAM teams had their own curriculum and timeline separate from our own, which limited the amount of features they were able to establish in TerpNav. Because the SEAM projects only lasted one semester each, the number of features we could implement in TerpNav was limited, and thus the factors we were able to study during our timeline were also limited. With more resources, we also could have evaluated TerpNav for a longer period of time, implemented specific experiments, and reached a larger number of participants. Thus, the amount of time we had with the SEAM teams, as well as our own team deadlines, limited the research scope of the project.

Chapter 10: Conclusions

Conclusions to Hypotheses

Team FASTR understood the need for a unified, information-rich mapping system at the University of Maryland. We took steps toward creating a comprehensive mapping system and expanded the body of research in two very important areas. Looking into the past, we found that scholarly research exploring the navigation needs of people with mobility issues was lacking despite a long history of attempts by government agencies to create mobility equality. We also found that research on forward-thinking community-sustainable geographic information systems was lacking despite our findings that community interaction and involvement-based information systems have been shown to be an effective way to distribute information. Our research focused on creating a product that used the information distribution powers of a community-sustainable geographic information system to address the navigation information needs of people who use wheelchairs.

Based on the findings of our literature review, we made several hypotheses concerning wheelchair navigation and community sustainability. Through the analysis of interviews, surveys, and TerpNav usage logs, Team FASTR was able to reach conclusions about our hypotheses and answer our guiding research questions.

H1 stated that people using wheelchairs commonly experience problems navigating the University of Maryland College Park campus. We were able to explicitly confirm this hypothesis by interviewing a segment of the population of people using wheelchairs. In our interviews with people using wheelchairs, interview participants told numerous stories of difficulties navigating campus using a wheelchair, suggesting that there are often problems for any person attempting to navigate campus (see the Interviews: Need for a System section).

H2 stated that there is a need for a navigation system such as we have proposed in the population of people at the University of Maryland College Park. This hypothesis had no bearing on the specific population of people who use wheelchairs. In retrospect, we did not address this hypothesis directly with our research because we assumed it to be true in the creation of TerpNav.

H3 stated that there is a need for a navigation system such as we have proposed in the population of people using wheelchairs. The results of our interviews confirmed this hypothesis as true. In our interviews with people using wheelchairs, all of our interviewees stated that there was a need for a navigation system to help with navigating campus (see the Interviews: Need for a System section).

H4 stated that an interactive map would be preferable over one that is not. Based on our findings from the analysis of other university maps and the survey of people who used TerpNav, we were able to tentatively confirm this hypothesis. More than half of the university maps we looked at included interactive components. In addition, we found that the use_again variable had a mean value of 5.1189 out of 7. This positive result was statistically significant, but we still question the degree of preference for an interactive system given that the mean was only one unit above the neutral option of 4 (see the Study of Other University Maps and Survey: Results and Discussion sections).

H5 stated that a community-sustainable map would be preferable to one that is not. Our survey results found the mean value for community_sustainable_trust to be

4.833 on a scale of 7. This suggests that more than half of the survey respondents would trust a sustainable map were it in place (see the Survey: Future Community-Sustainable Map's Potential section). Our research, however, did not directly addressed the preference for a sustainable map over a nonsustainable map. We have proposed future research to address this hypothesis in the Recommendations section.

H6 stated that people will be satisfied with our campus map system and therefore want to use it. Our survey results found that the mean value for use_again was 5.1189 out of 7 (see the Survey: The Current Map section), which supports H6.

H7 stated that people using wheelchairs will be satisfied with our campus map system and want to use it. This hypothesis was inconclusive because our survey received zero responses from people who acknowledged using wheelchairs; however, all of the interviewees stated that they would be willing to use the system and that it would improve their everyday life (see the Interviews: Results and Discussion and Survey: Survey Conclusions section). This observation suggests that people using wheelchairs would be satisfied with the system. Further study is necessary to confirm the usefulness of TerpNav for people using wheelchairs, which is also addressed in the Recommendations section.

H8 stated that a community-sustainable map can potentially be more current and reliable than a nonsustainable map, through community participation. Our literature review suggests this hypothesis to be true with the theoretical discussion of the knowledge gap. The knowledge gap occurs when information in a sustainable information system is only updated at certain time intervals, as in an analogous nonsustainable information system. However, with a sufficient user base, a sustainable information system can avoid this knowledge gap by providing reliable, current information (see the Literature Review: Sustainability section). An experiment to determine whether TerpNav, a sustainable information system, is reliable and up-to-date is discussed in the Recommendations section.

H9 stated that an area is best known by the people who spend time in it on a regular basis. The results from the user survey support this hypothesis. We found that there was a correlation coefficient of –0.58895 between familiar_diff, which measured the difference between perceived knowledge of the campus before and after using TerpNav and years on campus. This data suggests that upperclassmen, who presumably have spent more time on campus than underclassmen, already knew more about the campus before using TerpNav than underclassmen and were, therefore, able to learn less from using TerpNav (see the Survey: Results and Discussion section).

H10 stated that people using a sustainable map will want to participate and keep the map up-to-date. We were not able to address this hypothesis conclusively through our research. Although analysis of the survey results initially seems to support this hypothesis (see the Survey: Results and Discussion section), analysis of TerpNav's usage logs contradicts the survey results. Comparing the number of times people used TerpNav and the number of reported errors that were logged over 6 months of use by the community shows that only a small percentage of sessions resulted in a reported error (see the Rollout and Testing Phase: Errors Reported section). Results from the survey seem to show that if more interactive, participatory features were established in TerpNav, people would want to participate in keeping it up-to-date. Further study on this hypothesis is needed.

Recommendations

Although Team FASTR was able to draw useful conclusions from the experiments and analyses within this research study, there are a number of ideas and concepts that we envisioned as additional features and capabilities of TerpNav but were unable to incorporate during the study's timeframe. A full list, including descriptions, of these ideas can be found in Appendix I. Additionally, there is still much that can be learned and investigated by further research in the area of community sustainability and its application toward geographic information systems. For that reason, Team FASTR proposes the following for future research:

To determine the usefulness of TerpNav to people using wheelchairs, one of the defined purposes of our research, it is necessary to conduct at least one more user survey and ensure that some of the respondents use wheelchairs. The results of this survey would help address H7.

Team FASTR implemented the "Report Error" feature and the use of OpenStreetMap in an effort to lay the foundation for community sustainability within TerpNav to answer our third research question, "What properties of the community-sustainable system will enable and attract participation by the community?" However, further research on how to make TerpNav community sustainable is also needed. No method of directly editing TerpNav currently exists. TerpNav's current functionality allows users to suggest changes by reporting errors on the map and adding and removing localized information such as events and notes, but changes affecting the map's underlying geographic data must be implemented by an administrator. Future analysis on TerpNav's sustainability could determine if the conclusions reached in our research study would have been reached if the map's geographic data could be edited. This research could help determine whether there is a relationship between what information users are able to edit and the amount of user participation in maintaining the map's reliability in real time.

In our particular research study, we focused on the needs and desires of people who use wheelchairs; however, further research can address many different sustainability issues. For example, one potential research study could examine the impact of incentives on participation in a community-sustainable system. Further research would need to investigate the details of the incentives and the best type of incentive to attract participation the most efficiently. For example, monetary benefit, in which a group of users is paid for updating the map, could potentially lead to a different level of participation than altruistic benefit, in which a group of users edit the map for the benefit of helping the community at large. A close analysis of other sustainability issues, including the impact of incentives, could reveal the best structure for a community-sustainable system, meaning one that attracts the highest levels of participation from the community.

Appropriate metrics to determine specific aspects of sustainability also need to be devised from future research. For instance, future research on community-sustainable geographic information system should investigate methods to determine the accuracy of geographic information, methods to determine the impact of an edit, and methods of organizing edits in a systematic and controlled approach. To do this, an easy-to-use interface that allows people to edit anything on a community-sustainable map would also need to be developed. Metrics require further research because they determine the level of impact of changes. For example, a change in the boundaries of a large field might be a large but innocuous edit, whereas the addition of a curb cut, although a small edit, might have large implications for some users; thus, the differences in these two edits show that it is not trivial to differentiate the level of impact of these changes.

Further investigation into reliability checking should also be conducted. Several of the reliability-checking schemes that Team FASTR considered use the community to check the accuracy of an individual user's edit, although we were not able to implement any of these methods. Included in reliability-checking methods are an "after-use" method, a "change-rating" method, a "frequency of edit-request" method, and the "free edits" method. The "after-use" method allows a user to rate given information based on how correct, easy, or beneficial they think the given information is. The "change rating" method asks users to rate the edits made by other users for accuracy or usefulness. The "frequency of edit-request" method uses computer algorithms to automatically implement edits after a specific threshold for how many users request the edit is met. The "free edits" method allows any user to freely change anything with no restrictions or reliability checking in hopes that users will self-moderate the content. Investigation into different reliability-checking schemes would allow a researcher to conclude the best way to ensure the reliability of information in a community-sustainable system.

Another study could be designed to determine whether different privilege levels should exist in the community of users and how these levels should be implemented. If one of the rating reliability-checking schemes is implemented, a user's level of privileges could be based on his or her rating for quality of edits. Trying different methods of structuring the privilege levels would help to determine which structure lends itself best to community sustainability.

Future research could also help to support H5, which states that a community-sustainable map is preferable to one that is not community sustainable. A comparison study involving various community-sustainable and nonsustainable maps would help to determine whether H5 is supported or rejected.

Geographic information changes over time. In order to ensure that a community-sustainable information system stays up-to-date with these changes, a longer study is desired. For instance, a long-term study would be required in order to determine if a reliability-checking scheme or an incentive structure, as proposed above, is effective. Thus, future research should involve studies and analyses with research durations spanning longer than what was capable of this research study.

Final Remarks

TerpNav's success demonstrates that community-sustainable information systems may be a viable alternative to centrally maintained information systems that are less easily specialized to serve broad community needs. We conclude this because TerpNav has been preliminarily shown to be an effective map based on information obtained in a sustainable context. A sustainable map can be more readily updated to address the needs of people with special interests, such as people who use wheelchairs. Our research has confirmed that TerpNav is an effective first step in the direction of an easy-to-use, interactive, and sustainable map.

Appendices

Appendix A: Team Achievements

What	***Where***	***When***	***More information***
Presented at the 2008 Telehealth and Assistive Technologies (TAT) Conference	Baltimore, Maryland	April 16-18, 2008	www.iasted.org/ conferences/pastinfo-618.html
Placed 2nd in the 2008 Vid/Terp Competition	University of Maryland – College Park, Maryland	April 25, 2008	www.newsdesk.umd. edu/undergradexp/ release.cfm?ArticleID= 1647
Featured during Maryland Day 2008	University of Maryland – College Park, Maryland	April 26, 2008	~
Featured in "A Map Is just a Map, Right?"	*Between the Columns*	July 2, 2008	See Appendix F.
Used in Fall 2008 Locator Booths	University of Maryland – College Park, Maryland	September 2-3, 2008	~
Featured in "Speeding up the Campus Crawl"	*The Diamondback*	September 8, 2008	See Appendix F.
Named Best University Campus Represented in OpenStreetMap	Weait.com	September 30, 2008	www.weait.com/ content/which-university-campus-best-represented-openstreetmap
Adopted by the University of Maryland Visitor Center as the primary resource for events and visitors	University of Maryland – College Park, Maryland	August 2008	~
Adopted by the University of Maryland as the university's standard pedestrian map	University of Maryland – College Park, Maryland	November 2008	www.umd.edu/ CampusMaps/ campus_maps.cfm
Cited as "Best Practice" at the Collegiate Information and Visitor Services Association (CIVSA) conference	~	November 2008	~
Granted $15,000 Campus Student Technology funds to provide TerpNav to the university community	University of Maryland – College Park, Maryland	December 10, 2008	~
Featured for pedestrian map routing	Weait.com	February 1, 2009	www.weait.com/ content/pedestrian-map-routing

Appendix B: Spreadsheet of Other University Maps

Name	School Rank (2008)	Hyperlink	Details about Buildings	Drawn/ PDF/ Satellite	Best Maps	Distance?	Wheel-chair routes?	Layers	Buildings Clickable for more information	Searchable	Construction	Wheelchair Entrances	Handi-capped Parking	Indoor Mapping	Notes
Princeton University	1	http://www.princeton.edu/~pumap/	Picture, Departments, Phone numbers	Drawn	-	-	-	-	yes	list	-	-	-	-	Can search by genre of building
Harvard University	2	http://map.harvard.edu/	-	Drawn	-	-	-	-	-	yes	-	-	-	-	-
Stanford University	3	http://maps.stanford.edu/ada/	-	PDF	-	-	yes	-	-	-	-	yes	yes	Elevators	-
Upenn	4	http://www.facilities.upenn.edu/mapsBldgs/pennaccess.php3	Picture, Address, Short Description, Hyperlinks	Drawn	-	-	yes	-	yes	-	-	yes	yes	Elevators	-
CalTech	5	http://www.caltech.edu/map/	Picture	Drawn	-	-	-	-	yes	yes	-	-	-	-	Walking tour of campus available
MIT	6	http://whereis.mit.edu/map-jpg	Picture, Departments	Drawn/ Satellite	-	-	-	-	yes	yes	-	-	-	Floor plan	Medical, facilities and parking maps separate
Duke	7	http://maps.duke.edu/	Address	Drawn	-	-	-	-	yes	yes	-	-	-	-	-
Columbia	8	http://www.columbia.edu/about_columbia/map/	-	PDF	yes	-	yes	-	-	-	-	yes	yes	Elevators	-
Uchicago	9	http://maps.uchicago.edu/campus.shtml	Picture, address	Drawn	yes	-	yes	-	yes	list	yes	yes	yes	-	Accessibility information available upon zooming
Dartmouth	10	http://www.dartmouth.edu/~maps/campus/scrollable.html	-	Drawn	yes	-	-	-	-	-	-	yes	yes	-	-
Wash U	11	http://www.wustl.edu/maps/	-	Drawn	yes	-	yes	-	-	list	-	yes	yes	-	8 Types of maps, indoor mapping
Cornell	12	http://www.cornell.edu/maps/	-	PDF	-	-	-	-	-	-	yes	-	-	-	3 types of maps
Brown	13	http://www.brown.edu/Facilities/Facilities_Management/map_download1.php	-	PDF	-	-	yes	-	-	-	yes	yes	yes	Elevators	-
Northwestern	14	http://aquavite.northwestern.edu/maps/	Departments, hyperlinks	Drawn	-	-	-	-	yes	yes	-	-	-	-	Drawn map
Hopkins	15	http://webapps.jhu.edu/jhuniverse/information_about_hopkins/visitor_information/how_to_get_here/index.cfm#maps	-	PDF	-	-	-	-	-	-	-	-	yes	-	Homewood Campus. Has pedestrian path, guided tour
Rice	16	http://www.rice.edu/maps/maps.html	-	PDF	yes	-	-	-	-	-	-	yes	yes	-	-
Emory	17	http://emap.fmd.emory.edu/website/campus/index.htm	Picture	Drawn	-	-	-	-	yes	list	-	-	-	-	Has a map survey
Vanderbilt	18	http://www.vanderbilt.edu/map/map.cgi?mode=1	Picture, Departments, hyperlinks	Drawn	-	-	-	-	yes	list	-	yes	-	-	Barely interactive
Notre Dame	19	http://nd.edu/campus-and-community/campus-map/	-	PDF	-	-	-	-	-	list	-	-	-	-	Not interactive, has webcams
***Berkeley	20	http://dsp.berkeley.edu/access.html	-	PDF	yes	-	yes	-	-	-	-	yes	-	-	Map separate from main map
Carnegie Mellon	21	http://www.cmu.edu/oldhome/visitors/map/	-	Drawn	-	-	-	-	-	list	-	-	yes	-	Lists handicap parking, has virtual tour.

Name	School Rank (2008)	Hyperlink	Details about Buildings	Drawn/ PDF/ Satellite	Best Maps	Distance?	Wheel-chair routes?	Layers	Buildings Clickable for more information	Searchable	Construction	Wheelchair Entrances	Handi-capped Parking	Indoor Mapping	Notes
Carnegie Mellon	21	http://www.cmu.edu/oldhome/visitors/map/	-	Drawn	-	-	-	-	-	list	-	-	yes	-	Lists handicap parking, has virtual tour.
UVA	22	http://www.virginia.edu/Map/	-	PDF	-	-	yes	-	-	-	-	yes	yes	-	Accessible map separate from main map
Georgetown	23	http://maps.georgetown.edu/	Departments, Upcoming Events, Pictures	Drawn	-	-	-	-	yes	yes	-	-	-	-	-
***UCLA	24	http://www.transportation.ucla.edu/portal/pdf/parking/0807_dpmap.pdf	-	PDF	-	-	-	-	-	-	-	-	yes	-	-
***Umich Ann Arbor	25	http://uuis.umich.edu/cic/directions/index.cfm	-	Satellite	-	-	-	-	-	-	-	-	-	-	Not interactive
USC	26	http://www.usc.edu/about/visit/upc/	-	PDF	-	-	-	-	-	list	-	-	-	-	Not interactive
***UNC	27	http://www.unc.edu/visitors/mapshome.html	-	PDF	-	-	-	-	-	-	-	-	-	Elevators	Many maps, no accessibility though
Tufts	28	http://inside.tufts.edu/compass/	Picture, Services	Satellite/ Drawn	yes	-	-	yes	-	yes	-	-	yes	-	Many layers, one is handicapped parking
Wake Forest	29	http://www.wfu.edu/visitors/directions.html	-	PDF	-	-	-	-	-	list	-	-	-	-	Not interactive
Lehigh	30	http://www3.lehigh.edu/about/maps/interactive/index.html	Pictures, Short Description	Drawn	yes	-	-	yes	yes	yes	-	yes	yes	-	Flash based, layering (including wheelchair access), slow load time
Brandeis	31	http://my.brandeis.edu/map/	Department, Hyperlinks, Phone numbers	Drawn	-	-	-	-	yes	-	-	-	-	-	Has walking paths
W&M	32	http://mason.wm.edu/Mason/Maps/	-	PDF	-	-	-	-	-	-	-	-	-	-	Not interactive
NYU	33	http://www.nyu.edu/about/virtual.html	-	Drawn	-	-	-	-	yes	list	-	-	-	-	Photo tour
Rochester	34	http://www.rochester.edu/maps/	Pictures, Movies, Short description	Drawn	-	-	-	-	yes	yes	-	-	-	-	Good building details
Georgia Tech	35	http://gtalumni.org/map/	Picture	Satellite/ Drawn	-	-	-	yes	yes	yes	-	-	-	-	-
BC	36	http://www.bc.edu/about/maps.html	-	PDF	yes	-	yes	-	-	-	-	yes	yes	-	-
Wisconsin	37	http://www.map.wisc.edu/	Departments	Drawn	-	-	-	-	yes	yes	-	-	-	-	Great wheelchair info
UCSD	38	http://maps.ucsd.edu/Default.htm	-	Satellite	-	-	-	-	yes	yes	yes	-	yes	-	Wheelchair accessible parking, no legend on map
***Uillinois	39	http://www.uiuc.edu/ricker/CampusMap	ADA site hyperlinked	Drawn	-	-	-	-	yes	yes	-	yes	-	Elevators	Wheelchair accessibility only through building links
Case	40	http://www.case.edu/cgi-bin/campusmap	Picture, Departments	Drawn	-	-	-	-	yes	yes	-	-	-	-	Parking spots when searched

Name	School Rank (2008)	Hyperlink	Details about Buildings	Drawn/ PDF/ Satellite	Best Maps	Distance?	Wheel-chair routes?	Layers	Buildings Clickable for more information	Searchable	Construction	Wheelchair Entrances	Handi-capped Parking	Indoor Mapping	Notes
Uwashington	41	http://www.washington.edu/home/maps/ https://www.washington.edu/admin/ada/mmap.pdf	-	PDF	yes	-	yes	-	-	-	yes	yes	yes	-	-
UC Davis	42	http://visit.ucdavis.edu/map/	Departments, Hyperlinks	Drawn	-	-	-	-	-	yes	-	-	-	-	Virtual tour, not interactive map
RPI	43	http://www.rpi.edu/virtual_tour/zoomify/index.html	-	Drawn	-	-	-	-	-	yes	-	-	-	-	Virtual tour
UT Austin	44	http://www.utexas.edu/maps/	-	Drawn	-	-	yes	-	-	-	-	yes	yes	-	Not main map but directly accessible
UCSB	45	http://www.aw.id.ucsb.edu/maps/	-	Drawn	-	-	-	-	-	list	-	-	yes	-	Accessible map is same as main map
UC Irvine	46	http://www.uci.edu/campusmaps.shtml	-	PDF	-	-	-	-	-	-	yes	-	yes	-	Not interactive
Penn State	47	http://www.campusmaps.psu.edu/explore/	Picture Departments, Hyperlinks	Drawn	-	-	-	-	yes	-	-	-	-	-	-
Uflorida	48	http://campusmap.ufl.edu/	Departments, Hyperlinks	Satellite	yes	yes	-	yes	yes	yes	-	-	-	-	One of the best with no wheelchair information
Syracuse	49	http://map.syr.edu/	Departments, Hyperlinks	Drawn	-	-	-	-	yes	yes	-	-	-	Elevators	-
Tulane	50	http://www.som.tulane.edu/cancer/images/buildings/uptownmap.html	Departments Hyperlinks	Drawn	-	-	-	-	yes	list	-	-	-	-	-
Yeshiva	51	http://www.aecom.yu.edu/home/map.htm	-	Drawn	-	-	-	-	-	-	-	-	-	-	-
Umiami	52	http://www6.miami.edu/maps/	-	PDF	-	-	-	-	-	-	-	-	-	-	
Pepperdine	53	http://www.pepperdine.edu/virtualtour/imap/	Pictures, Departments	Drawn	-	-	-	-	yes	yes	-	-	-	-	Virtual Tour
GWU	54	http://www.gwu.edu/~map/imap/	Picture, Departments	Drawn	yes	-	-	yes	yes	yes	-	yes	-	-	-
Ohio State	55	http://www.osu.edu/map/google.php	Picture, Department	Satellite	yes	-	-	yes	yes	yes	-	-	-	-	Interactive, but buggy
BU	56	http://www.bu.edu/maps/	-	Satellite	yes	-	-	yes	-	yes	-	yes	-	-	This map can look crowded
Rutgers	57	http://maps.rutgers.edu/	Picture, Departments, accessibility	Drawn	-	-	-	-	yes	yes	-	-	-	Elevators	-
Upitt	58	http://www.upj.pitt.edu/401/	-	Drawn	-	-	-	-	-	yes	-	-	-	-	Not interactive
Ugeorgia	59	http://maps.uga.edu/website/htmlviewer/hyperlink/viewer.htm	-	Drawn	-	yes	-	-	-	yes	-	-	-	-	Features not working on the map
Texas A&M	60	http://campusmaps.tamu.edu/	Picture Department link	Satellite	yes	-	-	yes	yes	yes	-	-	-	-	Uses Google Maps
Worcester Polytechnic Institute	61	http://www.wpi.edu/About/Visitors/campusmap.html	-	PDF	-	-	-	-	-	-	-	yes	-	Restrooms	Not interactive

Name	School Rank (2008)	Hyperlink	Details about Buildings	Drawn/ PDF/ Satellite	Best Maps	Distance?	Wheel-chair routes?	Layers	Buildings Clickable for more information	Searchable	Construction	Wheelchair Entrances	Handi-capped Parking	Indoor Mapping	Notes
Uconn	62	http://admissions.uconn.edu/virtualtour/search/	-	Drawn	-	-	-	-	yes	yes	-	-	-	-	Virtual Tour
Purdue	63	http://news.uns.purdue.edu/newsweb.maps.html	-	PDF	-	-	-	-	-	-	yes	-	yes	-	Not interactive
Uiowa	64	http://www.uiowa.edu/homepage/hub/tours.html	-	Drawn	-	-	-	-	yes	yes	-	yes	yes	-	-
Fordham	65	http://origin.web.fordham.edu/audience/tours/lc_map.shtml	Picture, Departments, hyperlinks	Drawn	-	-	-	-	yes	-	-	-	-	-	Lots of detail on buildings
Miami Ohio	66	http://www.miami.muohio.edu/about_miami/campusmap/	-	Drawn	-	-	-	-	-	-	-	yes	yes	-	Not interactive, virtual tour, separate map
Clemson	67	http://www.clemson.edu/campusmap/2007_11x17map.pdf	-	PDF	-	-	-	-	-	-	yes	-	yes	-	-
SMU	68	http://smu.edu/maps/campus.asp	-	Drawn	-	-	-	-	-	-	-	-	-	-	-
Uminnesota	69	http://www.morris.umn.edu/visitor/UMMMapLarge.gif	-	Drawn	-	-	-	-	-	-	-	-	-	-	Not interactive
Virginia Tech	70	http://www.maps.vt.edu/	-	PDF	yes	-	yes	-	-	-	yes	yes	yes	Elevators	Good accessible map
Udelaware	71	http://chico.nss.udel.edu/buildings/	Picture, Facilities, Departments, Hyperlinks, Shuttle	Drawn	-	-	-	-	yes	yes	-	-	yes	-	-
Michigan State	72	http://maps.msu.edu/interactive/	Picture	Satellite	-	-	-	yes	-	yes	-	-	-	-	Not interactive
Stevens	73	http://www.stevens.edu/main/maps/hoboken.html	-	PDF	-	-	-	-	-	-	-	-	-	-	Not interactive
Baylor	74	http://www.baylor.edu/map/	-	Drawn	-	-	-	-	-	-	-	yes	-	-	Arrows for wheelchair entrances
Indiana	75	http://www.iupui.edu/maps/campusmap.htm	Pictures	Drawn	-	-	-	-	yes	list	-	-	-	-	Decent map
Brigham Young	76	http://map.byu.edu/	Picture, Departments	Satellite	-	-	-	yes	yes	yes	-	-	-	-	Hybrid of Googlemap and Drawn map
UCSC	77	http://maps.ucsc.edu/	Departments	PDF	yes	-	yes	-	-	-	-	yes	yes	Elevators	-
UC Boulder	78	http://www.colorado.edu/campusmap/	Picture, Department	Drawn	-	-	-	-	yes	yes	-	-	-	-	Not interactive
St Louis Univ	79	http://www.slu.edu/campusmap/	Departments	Drawn 3D	-	-	-	-	yes	yes	-	-	-	-	Not interactive
SUNY Binghamton	80	http://www.binghamton.edu/maps/campus.html http://eventscenter.binghamton.edu/access.htm	Picture, Departments, hyperlinks	Drawn	-	-	-	-	yes	yes	-	-	-	-	-
Marquette	81	http://www.marquette.edu/student/ugrad/campusmap.shtml	-	Drawn	-	-	-	-	-	yes	-	-	-	-	Not interactive
SUNY ESF	82	http://www.esf.edu/maps/	-	Drawn	-	-	-	-	-	-	-	yes	-	-	Not interactive

Name	School Rank (2008)	Hyperlink	Details about Buildings	Drawn/ PDF/ Satellite	Best Maps	Distance?	Wheel-chair routes?	Layers	Buildings Clickable for more information	Searchable	Construction	Wheelchair Entrances	Handi-capped Parking	Indoor Mapping	Notes
NC State	83	http://www.ncsu.edu/campus_map/	Picture, Departments	Drawn	-	-	yes	-	yes	list	-	yes	yes	Elevators	-
U Denver	84	http://www.du.edu/maps/upark.html	-	Drawn	-	-	-	-	-	yes	-	-	yes	-	Not interactive
American	85	http://www.american.edu/maps/campus.htm	Picture	Drawn	-	-	-	-	yes	list	-	-	-	-	-
Iowa State	86	http://www.fpm.iastate.edu/maps/	Picture, Department, hyperlinks	Drawn	yes	-	-	yes	yes	yes	yes	yes	yes	Elevator, Restroom, Floorplans	-
Kansas	87	http://www.maps.ku.edu/	Picture, Departments, hyperlinks	Drawn 3D	-	-	-	-	yes	yes	-	-	-	-	-
Alabama	88	http://tour.ua.edu/	-	PDF	-	-	-	-	-	-	-	yes	yes	-	Not interactive, has security phones
Missouri	89	http://accessibilitymap.missouri.edu/viewer.htm	-	Drawn	yes	-	-	yes	-	yes	yes	yes	yes	Elevators	-

Note: The University of Maryland's five peer institutions, as established by the State and University of Maryland President Dr. C. D. Mote, Jr., are denoted on the spreadsheet with three asterisks preceding their names.

Appendix C: Interview Questions

In this interview, I am studying wheelchair navigation at the University of Maryland in order to help in the development of a portable navigation system for the campus that I will refer to as GeoWiki. I will be asking you about your opinions of the proposed system, your personal preferences for what the system should include, and your opinions about the sustainability of the system. The information from this interview will be used to help us gain a better understanding of our user base before we begin to build our product. This interview will take about 30 minutes, in which I will ask you open-ended questions. We will do our best to keep your responses confidential. Your participation is voluntary and you may discontinue your participation at any point during the interview. In addition, you may choose not to answer a particular question if you do not want to. I plan to record our interview to make sure that I can develop accurate notes about your answers. Do you understand the statement I have just read? Do I have your permission to go ahead and begin the interview?

1. Do you use any navigation devices to help you find your way around the campus? (Possible prompts: print maps, PDAs, GPA devices)

1b. If so, what devices do you use?

2. Do you have any difficulties in navigating the campus now?

2b. If so, what?

My team and I plan to create a computer software program which will aid the navigation of people with disabilities, specifically people who use wheelchairs, by generating wheelchair navigable routes of travel on the University of Maryland, College Park campus. From now on, I will refer to the software program as "GeoWiki." GeoWiki will incorporate a map of the University of Maryland, College Park campus and floor plans of select on-campus buildings. GeoWiki will be available on portable 'Global Positioning Systems' (GPS) enabled devices and on personal computers. GeoWiki will use a user's defined input, such as 'Start' and 'End' locations, and personal preferences to output the best route for that user to travel.

3. Do you think there is a need for a system like this?

If the system existed:

4. Who would use this system?

5. How willing would you be to use it?

6. How can we maximize this?

7. In what situations do you believe you would use this system?

8. Given our description of our system, what features would make this system more useful to you?

9. What conditions would you want the system to consider when choosing a path? (Possible prompts: steepness of hills, stairs, location of curb cuts, flooding possibilities, lighted paths, crowded walkways)

10. What facilities and/or objects would you like the system to be able to locate on campus?
    (Possible prompts: handicapped accessible bathrooms, handicapped accessible water fountains, elevators, soda machines, newspapers)

11. What possible problems do you foresee with the system we are aiming to create?

12. How might you suggest solving those problems?

13. Would this system help alleviate current problems navigating campus?
    If so…

13b. What problems would this system help alleviate?

One of the main issues that need to be considered in creating our system is its sustainability. A program's sustainability is defined as its capability of being maintained at length without interruption of weakening. Since there are constantly changes to our campus setting, it is important that our GeoWiki system map be able to keep up with them. We are hoping to make our system community-sustainable by allowing users to freely edit the database.

While allowing users the freedom of editing the database may seem like a great idea, there are still difficulties and dangers that we will likely encounter. Of these, one of the most potent problems we will face is vandalism. Among the population of users of our system, there are bound to be deviants. These users could potentially give false information to the GeoWiki system in an attempt to mislead others, harm the system, or to generally create chaos within the system. One of the measures we plan to have in place to prevent acts of vandalism is a log of activity which will contain dated backup copies of maps. We will also have each user of our system register their identity with the database so that troublemakers can be handled efficiently. In these ways we hope to deter vandals from hurting our GeoWiki system.

14. What could improve the sustainability of the system?

15. How willing would you be to update the system?

16. What would motivate you to update the system?

17. How much would you trust the system given that it can be updated by other users?

18. What sustainability problems, if any, do you foresee?

19. Should all users be given access to update the system?
19b. If not, what privileges should be granted to each user?

Assume that we have a community sustainable system….

20. Do you think the system would improve your everyday life?
If so…
20b. How do you think this system would improve your everyday life?

21. Do you think the system will have a long-term impact on the community?
21b. If so, what impact on the community do you think the system will have?

Demographic Questions

22. Would you please describe in detail your current level of accessibility? (prompts: full use of arms, full use of legs)

23. What sort of equipment, if any, do you use to aid your daily travel?

24. Do you commonly use the assistance of a service to navigate unknown areas? (prompts: an individual, a bus, ParaTransit)
24b. If so, how often?

25. Are there any places on campus that you have been unable to reach due to your disability or equipment?
25b. If so, where?

26. Are you able to use a computer?
26b. If so, how often do you use a computer?

27. Do you require any special assistance in using a computer?

28. Are you able to use a handheld device?

29. Do you require any special assistance in using a handheld device?

30. Do you own a PDA or similar device?
30b. If so, how often do you use it?
30c. Could you use it while traversing the campus?

31. Where do you live on campus?

32. How many semesters have you been on campus?

33. How well do you feel you know the campus?

34. Do you have any other questions or comments?

Thank you for taking the time to do this interview with us. Your answers will be valuable in shaping our product into a better one. If you know anyone else who uses a wheelchair and would be interested in participating in an interview, please encourage him or her to contact us. Please enjoy your gift certificate.

Appendix D: Phase One TerpNav Development Concept Screenshots

Figure D1: Concept Screenshot 1

As this figure depicts, we wanted TerpNav to be able to find a route between a starting and ending location. We also wanted the option of having route filters to filter out necessary information for our target population,—people using wheelchairs. In addition, we did consider including step-by-step instructions, as the image shows.

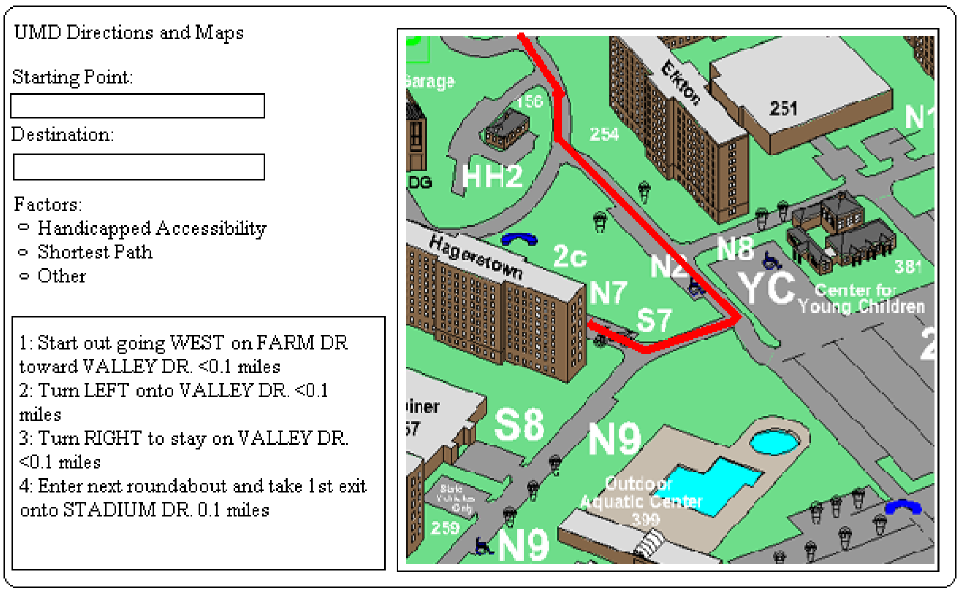


Figure D2: Concept Screenshot 2

This figure also shows a concept screenshot designed by our team. In this screenshot, however, we used GoogleMaps as the base map. This design also does not incorporate step-by-step directions, although it does include a destination location and a filter option for wheelchair-accessible paths. In addition, this screenshot depicts a community-sustainable map feature, notes, which can be added anywhere on the map.

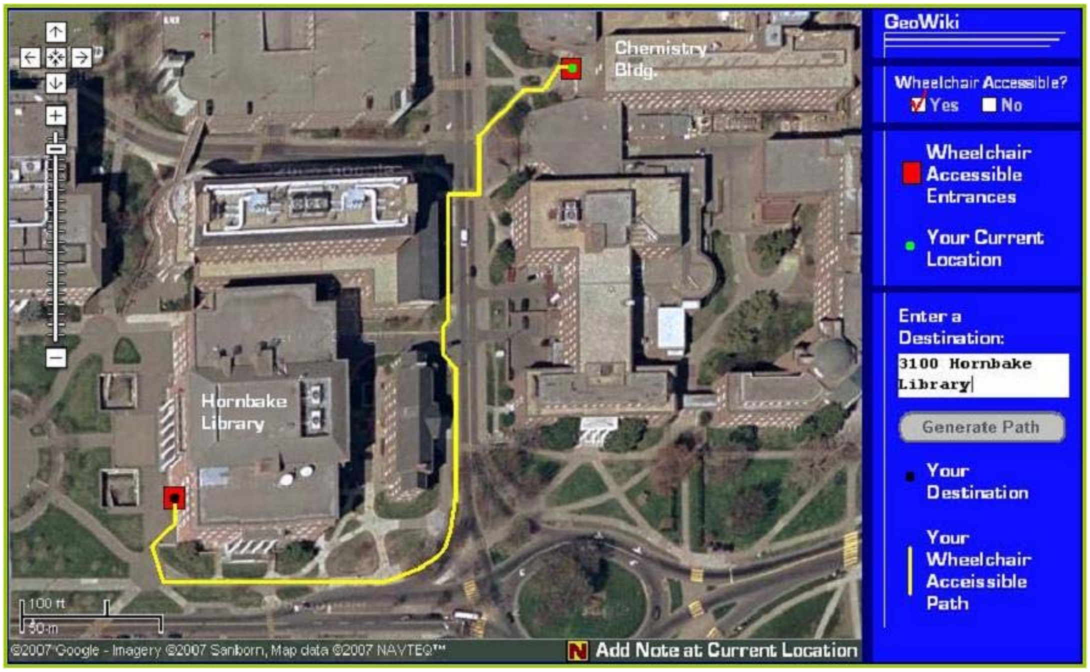
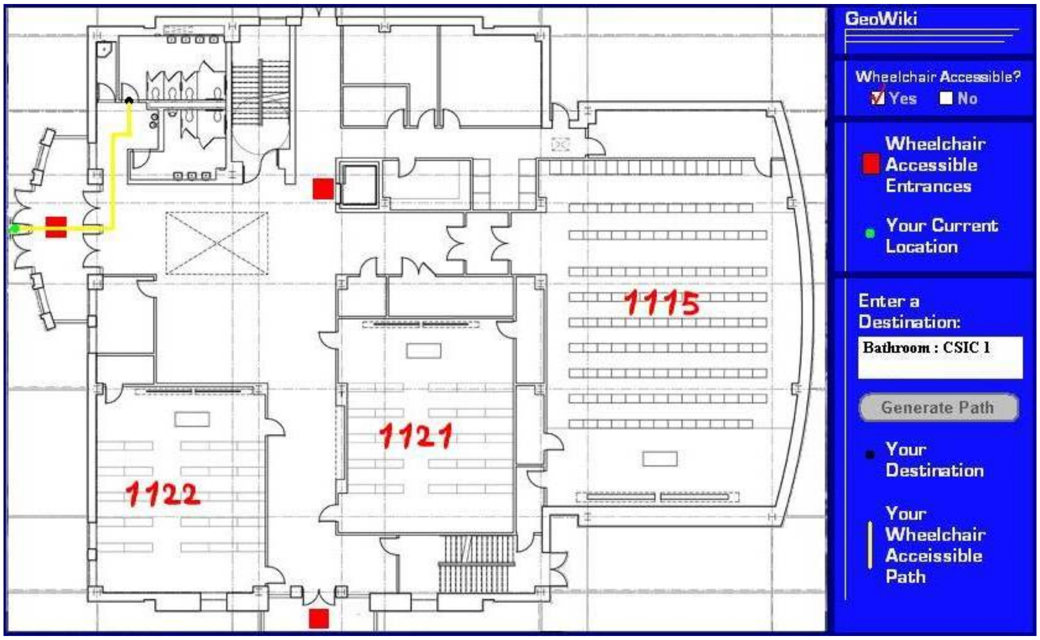


Figure D3: Indoor Component Concept Screenshot

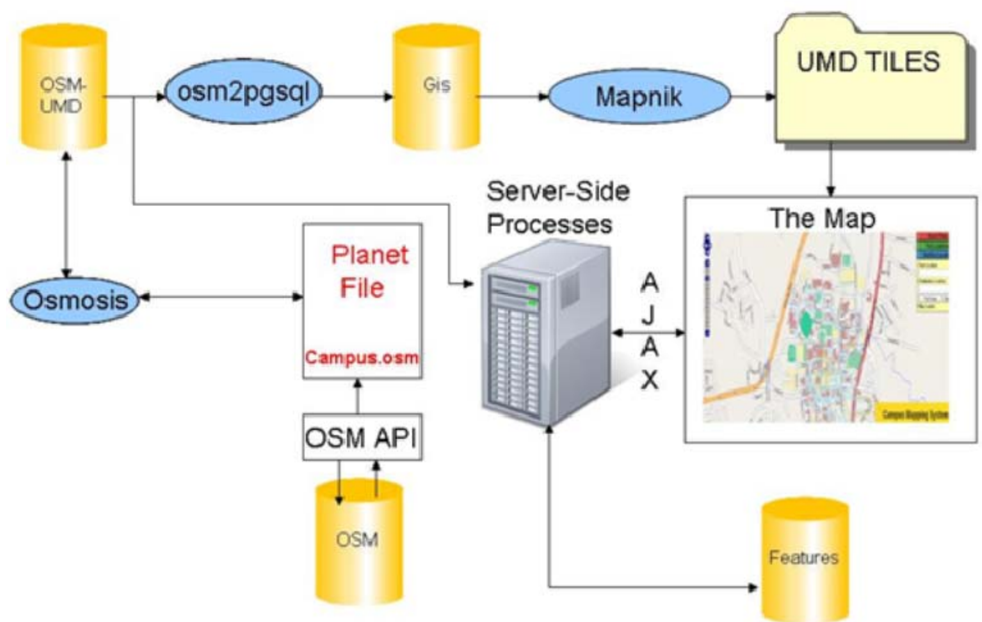
As the figure demonstrates, we originally wanted to incorporate indoor navigation information in TerpNav, including building floor plans labeling classroom and office numbers, as well as elevators and other important facilities.



Appendix E: Information Flow Diagram

Figure E1: Software Engineering at Maryland (SEAM) Team Information Flow Diagram for TerpNav

This figure diagrams the flow of information in the TerpNav system, as developed by the Software Engineering at Maryland (SEAM) teams for the purposes of our research.



Appendix F: Publicity Articles

Speeding up the Campus Crawl

By: Patsy Morrow

Posted: 9/8/08

Exactly how far is the walk from Denton Hall to Susquehanna Hall? What is the best way to get to the Stamp Student Union? Freshmen have long been asking these questions, but for the first time students can find the answers by accessing a website called TerpNav (www.map.umd.edu).

TerpNav was developed by a team of Gemstone students called Finding Alternative Special Travel Routes and a group of computer science students called Software Engineering at Maryland.

TerpNav is an interactive map of the campus where users can click on desired start and end points and the map will give them pedestrian routes and an estimated travel time, much like the website MapQuest.

The FASTR team focused on the wheelchair-using community for this map because they are "more affected by changes in their environment," senior mechanical engineering major and FASTR team member Jake Cigna said. In addition to providing precise directions along campus sidewalks, the user can also request directions to avoid construction and steep hills and to find curb cuts.

FASTR decided to focus on wheelchair access because "it was more focused on the community and a service that didn't exist," said senior mathematics major Laura Slivinski, who is also on the Gemstone team.

While the map was made with wheelchair-users in mind, it has been a great tool to new students at the university.

"It was pretty useful," freshman chemistry major Akshay Gandhi said. "I knew where the basic buildings were like Stamp, but I didn't really know where a building like Martin Hall was, so it was really useful in figuring those things out."

This is the first map of its kind at the university, and students are very appreciative of the services it offers because, unlike the university maps, "it has all the walking routes and not just streets," said freshman neurobiology and physiology major Theresa Chea.

The Gemstone team did a great deal of legwork to get their system up and running. They walked the campus, noting steep hills to avoid, checking to see if the paths based on previous campus maps were correct, and advertised their project.

FASTR, comprising 11 seniors, came up with the concept during the second semester of its freshman year. Since then, the group has been bringing the project to fruition. The team designed the map, and their group mentor, professor Jim Purtilo, paired it up early on with SEAM to develop the software and program the map. SEAM is an undergraduate program that pairs upper-level computer science students with other outside clients that might benefit from their expertise.

SEAM and FASTR designed the map to be a wiki map. With a wiki, like Wikipedia, anyone can edit or input information into the system to update the map. The idea behind it is that if there is a new construction project on the campus, students can input the information and users can avoid that route to class.

The Gemstone team members are the only ones who can add or change information on the map right now but users can report any errors and the team will evaluate the error. Cigna said he hopes the map will eventually be self-sustaining, so users can continue to use and update the map once the team members graduate.

University Initiatives

A Map Is Just a Map, Right?

By Susan Warren

Not in the information age. Today's digital maps serve as the carrier for a host of other bits of information about your neighborhood. They help you organize your world.

That's no less true at Maryland where the time-tested—some would say "old tech"—campus map is getting more than just a facelift. It's about to be turned into a "new tech" data structure to better serve both the campus community and the university's visitors. And students are leading the way with this campus map pilot project. Called Finding Alternative Specialized Travel Routes (FASTR), the Gemstone students-led project has a deeper research objective, which is to find what properties of an information system make it sustainable by the community. "In other words, how can we make it easy for everyone to help organize useful information, rather than rely on expensive centralized administration to maintain it for us?" asks Jim Purtilo, associate professor and associate chair of computer science. He is also mentor to the Gemstone team.

In order to experiment with their various ideas, members of Team FASTR needed a rich example and chose accessibility. Their pilot seeks to improve the quality of information about handicap access on campus.

Team FASTR commissioned the development of a dynamic pedestrian map that suggests routes, keeps track of which is wheelchair accessible and—important for their research questions—enables user participation in the updating of the map information.

"If a construction project or major event is temporarily blocking key pedestrian routes, then an inconvenience to many people can become a major disruption to someone in a wheelchair who needs to know other routing options fast," adds Purtilo.

"If FASTR is successful, then it will highlight what properties of the system prompt other members of the community to help update those options in real time."

Working Together for Better Access

To build their high-tech mapping tools, FASTR turned to another student group: Software Engineering at Maryland (SEAM). Run by the computer science department, SEAM is a software co-op that pairs student teams from upper-level software engineering classes with partners in industry or government to solve real customer problems. SEAM students, in one semester, built a prototype pedestrian maps system for the FASTR students.

Coincidentally, a group of campus stakeholders also were discussing possibilities for the development of a new campus map. The group, led by Gloria Aparicio Blackwell, assistant to the vice president of administrative affairs, and Susan Warren, associate director of conferences and visitor services, learned about the student project and immediately took steps to bring everyone to the table. Visitor Services, Facilities Planning, University Marketing, the Department of Transportation Services, the Office of Information Technology and others began collaborating on a wish list of potential future uses for this interactive map.

“An updated campus map is an important step to take before a project to assess ways to reduce traffic on Route 1 can take place,” says Douglas Duncan, vice president of administrative affairs. One of the wish list items includes the ability for people coming to campus to plug in their destination and get information on the best directions, most appropriate campus entrance and the closest parking.

“It’s a terrific sign of success for these students when new users enthusiastically embrace the project and want to explore its further development for campus-wide use,” says Purtilo, founder of the SEAM Co-op. “Our prototype is helping decision makers think through what they really want in a full-blown digital mapping system.”

The FASTR team will do its study on sustainability and assess user performance in the fall. In the meantime, the prototype campus mapping system is available for anyone to use at seamster.cs.umd.edu:8090/map/index.html. Give it a try and send feedback to: vcmap@umd.edu.

Posted on July 2, 2008

Comment:

This is a great project. I think this idea should be expanded and improved for all students with disabilities, new visitors on campus, and also include small maps around the campus. One of the assumptions is that each person did have a map with them. Map boards to find one’s location across campus can help and reduce the need to use paper. Great idea and awesome project.

Comment by Angelo Gomez — July 18, 2008 @ 2:12 pm

Appendix G: Survey Questions

Please fill out the following survey based on your use of the TerpNav system.

Use of the System

How many times did you use the system? (Estimate to the best of your abilities.)

- 0 times
- 1 time
- 2-3 times
- 4-5 times
- 6 or more times

What features of the system did you use? Check all that apply.

- Find route
- Start/End Locations (typing them in)
- Start/End Locations (clicking on map)
- Find Locations
- Route Filters
- Avoid Point
- Report Error

For what purposes did you use the system? Check all that apply.

- Find route to class
- Find wheelchair-accessible route
- Find route to meeting
- Find buildings
- Find bike path
- Get to know campus
- To improve the map
- Other *(free response)*

If you used the "Find Route" feature, how satisfied were you with the route the system gave you?

1	2	3	4	5	6	7	N/A
Not Satisfied						Very Satisfied	

If you used the "Find Locations" feature, how satisfied were you with its results?

1	2	3	4	5	6	7	N/A
Not Satisfied						Very Satisfied	

If you used the "No Stairs" Route Filter, how satisfied were you with its results?

1 2 3 4 5 6 7 N/A
Not Satisfied Very Satisfied

If you used the “Sloped Curbs Only” Route Filter, how satisfied were you with its results?

1 2 3 4 5 6 7 N/A
Not Satisfied Very Satisfied

If you used the “No Steep Inclines” Route Filter, how satisfied were you with its results?

1 2 3 4 5 6 7 N/A
Not Satisfied Very Satisfied

The current route filter choices are: No Stairs, Sloped Curbs Only, and No Steep Inclines. What other filters, if any, do you think are needed?
(free response)

What is the likelihood that you’ll use the system again?

1 2 3 4 5 6 7 N/A
Very Unlikely Very Likely

By what means would you use the system? Check all that apply.

- On a PDA
- On a cell phone
- On your personal computer
- In a computer lab on campus
- On a kiosk in Adele H. Stamp Student Union
- On a kiosk in McKeldin Library
- On a kiosk in the Visitors Center
- On a kiosk elsewhere, indicate where *(free response)*
- Other *(free response)*

What problems, if any, did you encounter when using the system? Please elaborate. (For example, incorrect route information.)

(free response)

What problems, if any, do you foresee with the system? Please elaborate.

(free response)

Sustainability
We are currently working on making the system community-sustainable, meaning that it will be able to be updated by users. Users will be able to fix errors and change the mapping data as they deem necessary. The system will be comparable to Wikipedia in that it will be maintained by the community of users. Please answer the following questions regarding this type of community-sustainable navigation system:

Would you update the system?

Yes No

What would motivate you to update the system? Check all that apply.

- You want it to be updated for others' future use of the program.
- You want it to be updated for your future use of the program.
- You thought the editing function was fun to use.
- You are interested in the project in general.
- You want it to become the official university map.
- Other *(free response)*

How much would you trust the data you receive from a community-sustainable system?

1	2	3	4	5	6	7	N/A
Not at all						Very	

Who would you trust to update the system? Check all that apply.

- All registered users
- A group of peer-approved users (known through review system)
- A staff administrator (working for the University)
- A student administrator (working for the University)
- A student administrator (not working for the University)
- People using wheelchairs
- A specific group of users
    - If so, please explain who: *(free response)*

What system would you prefer in order to see mistakes with the map addressed? Check all that apply.

- An administrator's contact information
- A 'report error' option
- A blog or community forum
- A link to a feedback form
- The ability to correct the information yourself

Do you think that your knowledge of campus will improve with continued use of the system?

1	2	3	4	5	6	7	N/A
Definitely not						Definitely yes	

Do you think that your use of the program will decrease over time?

1	2	3	4	5	6	7	N/A
Definitely not						Definitely yes	

Regarding the last question, why or why not?

(free response)

What would attract your future use of the system?

(free response)

Demographics

How old are you? *(free response)*

What is your status at the University?

- Freshman Undergraduate Student
- Sophomore Undergraduate Student
- Junior Undergraduate Student
- Senior Undergraduate Student
- Graduate Student
- Staff
- Faculty
- Visitor
- Other *(free response)*

If you are a staff or faculty member, how many semesters have you been working on campus?

(free response)

If you are a student, how many semesters have you been taking classes on campus?

(free response)

If you are not a student, staff, or faculty member, how often do you visit campus?

(free response)

Do you live on campus?

Yes No

Please check any of the following that you use on a regular basis around campus.

- Wheelchair
- Cane
- Walker
- Crutches
- Stroller
- Motorized scooter
- Bike
- Skateboard
- Rollerblades

How familiar with the campus were you before using the system?

1	2	3	4	5	6	7	N/A
Not at all						Very	

How familiar with the campus were you after using the system?

1	2	3	4	5	6	7	N/A
Not at all						Very	

What navigation systems or devices do you currently use to navigate the campus? Check all that apply.

- MapQuest
- Google Maps
- Yahoo! Maps
- Microsoft Virtual Earth
- In-car GPS navigation system
- UMD’s Online Parking Map
- Paper map from UMD’s Visitors Center
- None
- Other *(free response)*

Appendix H: Phase Two TerpNav Development Concept Screenshots

Figure H1: Concept Screenshot 1

This figure displays our Phase Two design concept regarding menu options. We wanted to include more community sustainability features in the menu, including the ability to add notes, events, and global avoids, as well as building information.

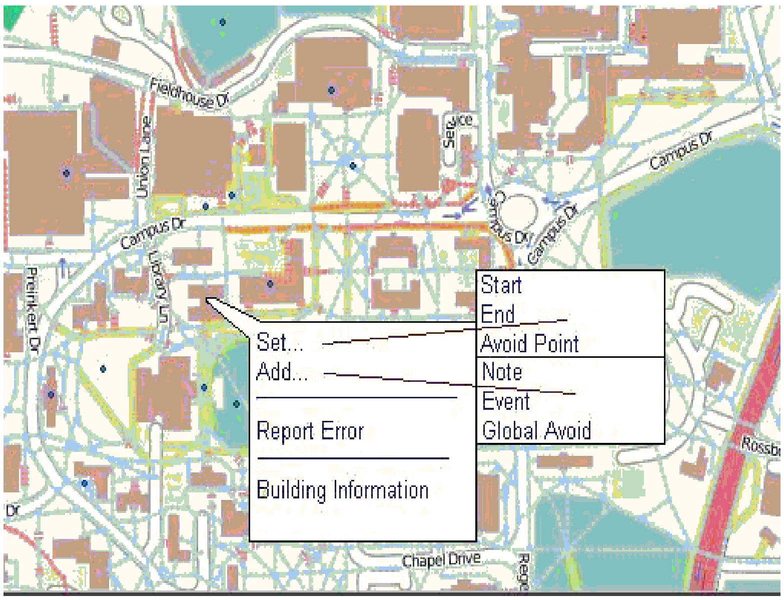


Figure H2: Concept Screenshot 2

As this figure displays, we also planned pop-up windows for building and event information to pop up when a building is clicked on. We wanted this information to be editable by all users so that it would be similar to a wiki.

Figure H3: Concept Screenshot 3

This figure depicts our idea for the “Notes” feature in the Phase Two TerpNav development. We wanted notes to be able to be written and updated by users.

Figure H4: Concept Screenshot 4

This figure depicts our idea for the “Report Error” feature in the second TerpNav version, including choices for the type of error present in the map.

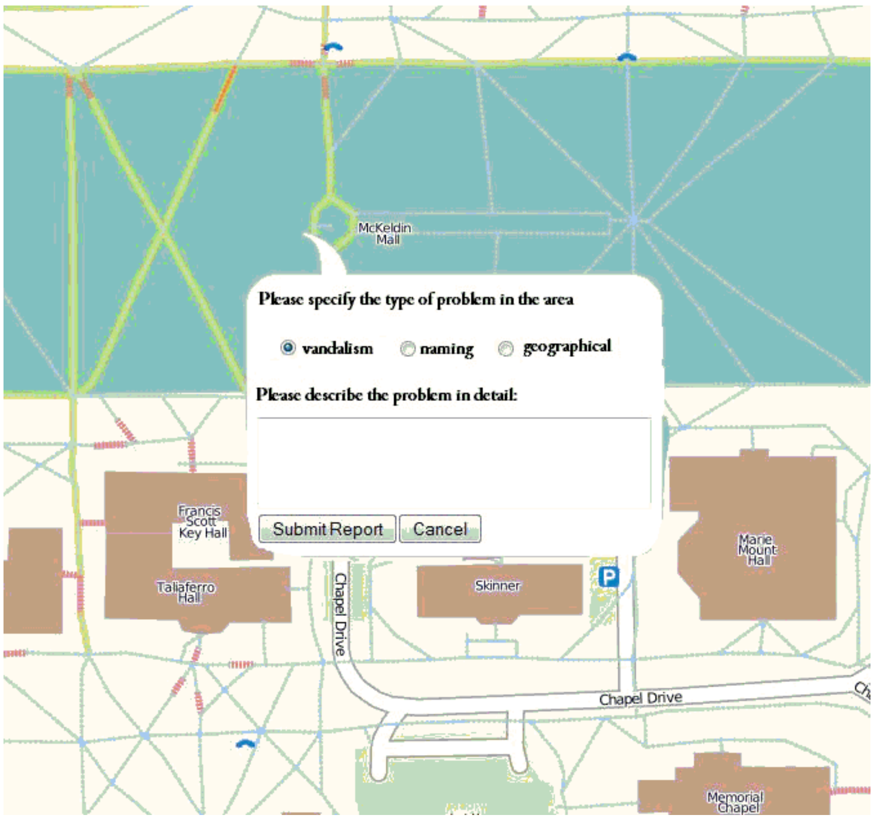
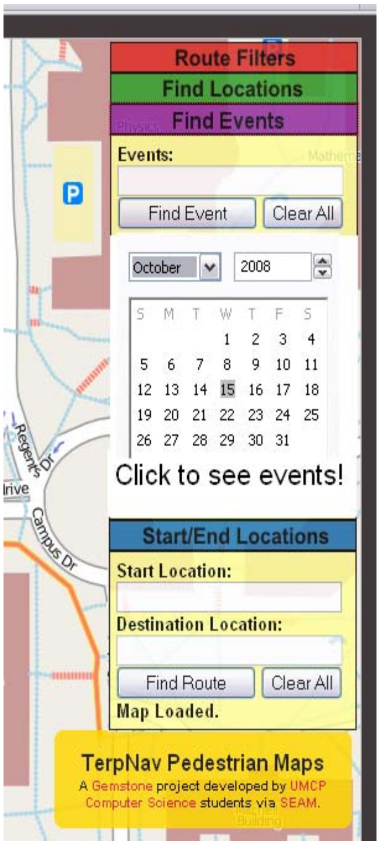


Figure H5: Concept Screenshot 5

This figure displays our idea for the “Find Events” tab, including a calendar in which users can choose to see all of the events listed on a certain date.



Appendix I: Additional Ideas

Over the course of this project, Team FASTR considered a number of related avenues for investigation, research questions, and ideas for new or different features for TerpNav. However, in order to remain within constraints on time and resources, we focused on only the ideas as presented in the body of this dissertation. The following is a list of the ideas that Team FASTR devised but did not incorporate into TerpNav. We include this list in the hope that these ideas may be incorporated into future versions of TerpNav.

User Edits

Our original TerpNav idea included the concept of having individual users sign in to the program and make needed changes to the map. Allowing all users who were willing to participate to edit the map is important to its sustainability. We initially wanted users to create a username and password so that changes made by each individual could be tracked by the whole community. Logging user changes could prevent vandalism, as the user might not be willing to make incorrect changes if he or she knows the community is able to see all of his or her actions. Another possible method for preventing vandalism is the use of individual user "ratings" or "levels" associated with the quality of map edits made. Similar to the ratings systems used on websites such as Ebay.com and Amazon.com, the community of users would be able to publicly rate the map editor, creating a measure of accuracy for each user.

Personal Profiles

With personal usernames and passwords, users could also create profiles containing their own personal route histories, usages, and preferences. For instance, if a user prefers to take one path instead of another, this information could be saved to his or her profile so that any calculated routes in that area of campus will automatically include the user's preferred route. Having profile pages could also lead to a social networking component of TerpNav: Users could upload their class schedules for public viewing so that their friends would be able to see where they would be at certain times. We also considered a "graffiti" feature, in which users could write notes to each other that would be linked to locations on the map and be visible only to specific people. However, we chose not to implement these features in the current TerpNav version because of the privacy issues associated with making class schedules and other personal information public. Additional features we considered that could be linked to specific user profile pages include personal speed (walking/running/biking), automatic filters (e.g., if a user always wants to avoid stairs), and specific types of events.

Routing Function

Although TerpNav currently provides the shortest route between two points, we considered several features to improve TerpNav's routing function. An improved routing capability could consider building shortcuts when providing a route, allowing users to walk through buildings instead of having to go around them. Similar to building shortcuts, it is also sometimes shorter to walk through parking lots than around them. The current routing algorithm does not consider all possible routes through a parking lot, and could be updated so that the total area of a parking lot is acceptable for use in giving the shortest route. Finally, we considered implementing an option to drag a given route from one path to another, as you currently can on GoogleMaps. A user could then change the route based on his or her preferences.

Route Output Options

We also wanted to provide more options for displaying TerpNav's route output. In addition to the visual route already provided, we wanted to provide written directions. Written directions would make it easier for the user to follow the route, especially while walking. However, because most walking paths on campus are not named (most are sidewalks), we researched outputting directions using landmarks, as this seemed to be the best way to navigate a large pedestrian area. We also considered outputting the directions audibly to address the needs of people with visual impairments.

Indoor Navigation

Originally, we wanted to include indoor mapping of every building on campus. By including indoor mapping, TerpNav would be able to navigate users to specific classrooms and offices while also pointing out notable landmarks such as elevators, stairwells, bathrooms, water fountains, and snack machines. Indoor navigation is very important to people who use wheelchairs, who must use elevators and handicapped-accessible bathrooms, as well as to other populations such as people who have diabetes, who may need to know the location of the nearest snack machine. Although one of the SEAM teams attempted to create an indoor navigation system, we were not able to incorporate their final product with TerpNav's use of OpenStreetMap due to scale and time constraints. The resolution of OpenStreetMap's data points was not adequate for the length scale required to build a virtual building, meaning that the SEAM team responsible for indoor navigation had to develop an alternate information repository and work cross-platform to meld at least two separate systems to work with each other. In addition, the task of re-creating every building on the University of Maryland College Park campus was daunting because it proved difficult to obtain accurate and complete floor plans for every building. We decided not to incorporate the indoor navigation features in order to concentrate on the core features of the outdoor navigation system, TerpNav.

Incorporation with Current University Services

The University of Maryland provides students with a program named Venus, which is an interactive course scheduling and registration program. Using Venus, a student inputs his or her classes, both required and optional, and the program outputs all possible schedules. The program incorporates the class locations and provides warnings if two back-to-back classes are too far apart from each other to enable the student to arrive to the second class on time. We considered integrating TerpNav into the Venus program so that students could see the fastest route between classes in each schedule option, giving TerpNav additional use and publicity in the university community.

We also wanted to connect TerpNav's navigation functionality with the university's Global Positioning System tracking system for its buses. The Univesity of Maryland's Department of Transportation Services (DOTS) runs an extensive bus operation that operates both on and off campus, and DOTS recently implemented a GPS tracking system called ShuttleTrac for all buses. If the ShuttleTrac service was incorporated into TerpNav, the map would be able to display one or all of the bus routes and their associated bus stops. We wanted a user to be able to click on a bus stop to display the arrival times of different buses at that particular bus stop, the precise service provided by ShuttleTrac. A more ambitious TerpNav layer would show the locations of all of the buses on campus in real time. If TerpNav was connected to the ShuttleTrac program, it would also be possible to try to combine bus routing information with pedestrian navigation, meaning that a user might be directed to take a bus for part or all of a route instead of walking.

In order for an event to show up in the second version of TerpNav, a user must manually input event information. We also considered making TerpNav's event addition process more semi-automated, given that many university webpages already display university events. We wanted TerpNav to automatically extract event information from other University of Maryland websites, including the university's main webpage, store it in its own database, and then display it to users. Although users would still be able to manually enter an event into TerpNav, making TerpNav's event population semi-automated might increase its usefulness.

Additional Layers

The second development of TerpNav provides the ability to choose whether or not to display events, user notes, and error reports, exhibiting TerpNav's use of layers. There are separate layers for events, user notes, and error reports, and the user is able to choose which layer he or she would like to see and use. We considered additional layers for TerpNav, including the locations of objects that are already in the map's database, such as parking lots and emergency phones, and objects that have not yet been incorporated into the map's database, such as shops, food services, and other points of interest.

Additional Filters

Although TerpNav already uses filters to avoid paths with stairs, steep inclines, and the lack of sloped curbs, we envisioned adding more filters that could be useful to the campus community and potentially increase user participation. Additional filter ideas included a bicycle path filter, a scenic filter, a weather filter, and a safety filter. A bicycle path filter would be useful to the large community of bicycle users on campus. A scenic filter would be useful to individuals looking to enjoy the campus' scenery. A weather filter would be useful during rain and snow storms, given that the ability to navigate the campus significantly changes during and after some storms. Rainfall sometimes causes areas of the campus to flood and some roads to turn into small rivers, and snow and ice can leave sidewalks covered or dangerously icy. The ability to avoid the areas that have been most affected by rain and snow could be useful for people who may have trouble navigating these obstacles. The safety filter would address the campus' concern for safety, as it could output either the best-lit areas of campus or the most populated route between two points.

Additional Features

There were additional features we considered adding to TerpNav. For example, TerpNav currently calculates a route's distance in a variety of metrics. It would also be useful to be able to approximate the amount of time it would take to navigate a route, although the user would have to choose his or her approximate speed. The difficulty in approximating personal speed was the primary reason we did not incorporate this feature. People who use wheelchairs, walkers, and bikes all move at different speeds, as do people walking. We also considered a feature that would provide users with the number of calories they would burn when traveling a certain path. This also brought up personalization difficulties, as the number of calories burned would also depend on speed and elevation. Lastly, we considered allowing a user to set a desired distance to travel and then having TerpNav output the route closest to that distance.

Editable Wiki Pages

In the second development of TerpNav, the bubble that pops up when a building is clicked on contains a hyperlink to that building's website and, if available, a link to a page showing the building's events, errors, and notes. Most buildings have a simple university-created webpage with the following content: a picture of the building; the building's code, number, and location in terms of the block in which it is located on the DOTS campus parking map; a list of any associated labs or organizations within the building; and, if available, a brief history of the building. In order to increase user participation in TerpNav, we wanted to combine this already-available information with the events, errors, and notes for a particular location, creating one building information wiki page. All fields in the building information wiki page would be able to be edited by any user, including additions, changes, and deletions.

Alternative Viewing Methods

Both versions of TerpNav are able to be viewed through Internet browsers that are generally found on personal computers. However, as technology capabilities increase, fully capable Internet browsers can be found on increasingly smaller devices such as personal digital assistants (PDAs) and cell phones. Making TerpNav compatible with small devices would allow users to use TerpNav as they walk around campus. In addition, incorporating GPS and/or WiFi location information with TerpNav could enable TerpNav to provide the user with directions based on his or her current location, possibly updating the directions as the user moves. This user experience could be more effective than giving the user all of the directions at a single time.

We also considered setting up map kiosks around campus, either outside or inside central locations such as the Adele H. Stamp Student Union. Kiosks would enable users to obtain directions to their desired destination at the current time. There would be no need to plan ahead and print directions for an entire day, as users could just use kiosks around campus throughout the day.

List of Abbreviations

ADA	Americans with Disabilities Act
AJAX	Asynchronous JavaScript and XML
CAD	Computer Aided Design
DSS	Disability Support Services
FASTR	Finding Alternative Travel Routes
GIS	Geographic Information System
GPS	Global Positioning System
GUI	Graphical User Interface
HTTP	Hypertext Transfer Protocol
IP	Internet Protocol
IRB	Institutional Review Board
IS	Information System
OSM	OpenStreetMap
PCDI	President's Commission on Disability Issues
PDA	Personal Digital Assistant
PDF	Portable Document Format
PHP	Hypertext Preprocessor
SEAM	Software Engineering at Maryland
SQL	Structured Query Language
UMD	University of Maryland
URL	Uniform Resource Locator

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