HARNESSING THE WEB TECHNOLOGY TO ENRICH VISUALLY CHALLENGED USERS NAVIGATION

Hulya Francis, Madjid Merabti
School of Computing and Mathematical Sciences, Liverpool John Moores University, James Parsons Building Byrom Street, Liverpool, UK

A. Taleb Bendiab
School of Computing and Mathematical Sciences, Liverpool John Moores University, James Parsons Building Byrom Street, Liverpool, UK

Keywords: Navigation, GIS, visually challenged users, web technology, tactile, auditory, olfactory senses.

Abstract: Navigating urban streets without sight is fraught with difficulty and is often dangerous. Visually challenged people rely on ancillary equipment such as a white cane to probe the immediate area in front of them as well as developing other pre-existing personal physiological senses such as tactile, auditory, and olfactory senses, to train themselves to walk along pavements. Conventional navigation systems based on geo-maps alone are of little use to a visually challenged pedestrian. Hence, there is a need to develop a navigation client-server system capable of providing information appropriate for a visually challenged pedestrian to use to navigate urban pavements. This paper describes a navigation system that includes an enriched information model and a technology to deliver such information in an easy-to-use, accessible fashion. The paper introduces the technical challenge to the creation of a digital database for the navigation server that stores appropriate data. A prototyped digital navigation model of Hoylake Town Centre, UK has been used to test and validate the proposed model. This paper describes the role and function, and outlines the architecture for the Web-based mobile computing location-based services navigation support systems.

1 INTRODUCTION

A visually challenged person will need training before being able to walk unaided, along a pavement. Pavements are cluttered with street furniture, vehicles sometimes parked on pavements, repairs and other obstructions. Obstructions are usually short-term and dynamic. As such, obstructions do not remain in place for any length of time and the pattern of obstruction changes frequently. Conventional navigation systems are based on maps that model the primary features of an area. The features of an area included in conventional maps are based on tangible objects that can be seen in the area e.g. roads, pavements, street furniture, buildings etc. Conventional navigation systems provide this information to support navigation such as that found in the ubiquitous NavSat systems. This information is of little use to a visually challenged pedestrian. A major challenge is the creation of a digital database for the navigation server that stores appropriate data. New digital models have been made of a case study area: Hoylake Town Centre, near Liverpool, United Kingdom. The digital database has been populated with micro tactile, auditory and olfactory data that visually challenged people will find useful. The digital database has been designed to provide information to make it easy for visually challenged pedestrians to navigate urban streets. Digital soundscapes for example provide information about the type and extent of sounds along the route; tactile maps contain information about the type and position of tactile surfaces or permanent wind draughts along the route; and olfactory maps provide information about the type and extent of smells along the route. Such data is used to enrich conventional data to assist visually challenged pedestrians find their way safely.

No conventional navigation systems provide

Francis H., Merabti M. and Taleb Bendiab A. (2007).
HARNESSING THE WEB TECHNOLOGY TO ENRICH VISUALLY CHALLENGED USERS NAVIGATION.
In *Proceedings of the Third International Conference on Web Information Systems and Technologies - Internet Technology*, pages 189-196
DOI: 10.5220/0001272401890196

information about obstructions in real time. The navigation system described here provides an opportunity for a user to record centrally information about current obstructions. Such information will become immediately available to others pedestrians in the vicinity. There is a need to ensure the delivery of information is appropriate to the user's particular needs. Recent advances in multimodal interface design offers a real way forward towards achieving this goal. Mobile location-based services' systems offer potential for delivering information in an unobtrusive, accessible fashion. A multimodal speech- and/or button driven interface on a thin client such as a PDA will help ensure wide acceptability of the system amongst visually challenged users. The navigation server will detect the client's position via an on-board GPS and will deliver user-specific, location-specific information in real time to help guide a pedestrian safely along an urban pavement.

Conventional information models are not appropriate for supporting navigation in visually challenged circumstances. Francis, H (1997) identified a non-traditional data-stream used by visually challenged people to navigate footpath routes in Lancaster University. Later research by Francis (Royal National Institute for the Blind, 1997) identified similar findings in research on blind pedestrians. Similar research carried out amongst visually challenged pedestrians in Liverpool (Francis, 2003-2005) noted the inability of conventional information models to supply unconventional data.

The conventional information model relies on sight being present. Recent technological advances to help overcome problems with navigation for people without sight have been based primarily on developing technology based on Geographic Information System (GIS) and Global Positioning System (GPS). Typical attempts have included audio systems that speak turn-by-turn instructions and, systems that make use of obstruction warning devices that employs infra-red technology. These approaches are limited by two fundamental shortcomings: (a) the size and complexity of the technology they use and (b) the fact that the information model they employ is derived for use by sighted people.

2 DATA MODEL AND DESIGN

Conventional map data do not provide the data normally used for navigation by visually challenged

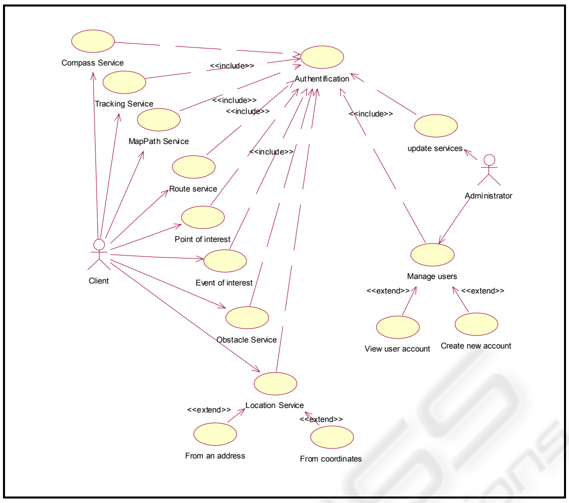

Figure 1: Application Use Case Diagram.

users. The success of the proposed navigation system hardware is dependent upon the right information being available. New digital maps that include the data required for navigation in visually challenged circumstances will need to be derived.

Using advanced Global Position System technology, digital maps of the micro environment are being assembled for the case study area. The digital maps will include data about significant sounds, tactile, olfactory features in the environment suitable for positioning. A range of digital maps will be prepared for inclusion in the navigation server including soundscapes, tactile positions, olfactory extents and auditory prompts.

The navigation system provides information to a user in a mobile location-based services environment. A user carrying a GPS-enabled PDA client will be able to query the navigation system about routes and services along a given route. The navigation system will provide information in real-time via a multimodal speech-driven interface.

Augmented navigation support in visually challenged circumstances will require both the inclusion of unconventional data as well as a new approach to information delivery. With this in mind it has been necessary to design a new generic navigation system to address the navigation needs of visually challenged people. The following Unified Modelling Language constructs provides an outline of the proposed design.

The use case diagram in Figure 1 shows all the services offered to a user, who can be either a simple client or an administrator.

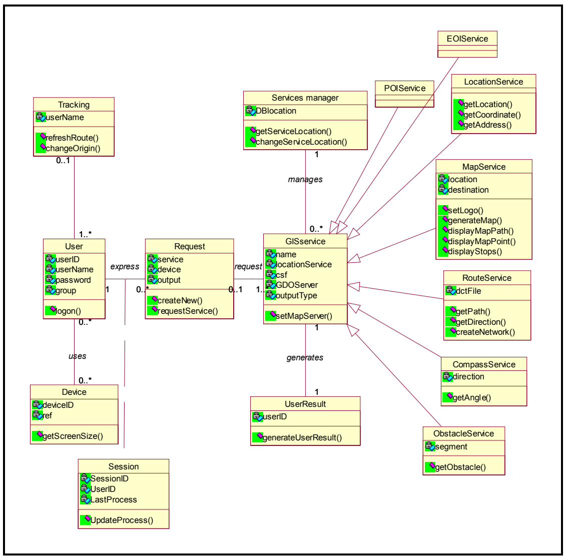

Figure 2: Class Diagram of the Application.

Figure 2 provides an overview of the available services in the system. The **location service** can be called by providing either an address (street name, street number or postcode) or coordinates. If called by providing an address, the service will display a map with the address highlighted or retrieve its coordinates. These coordinates can be then used by another service or another application in the case of a web service configuration. If called by providing coordinates, the location service will assign the nearest street to this point and return either the corresponding address on a text format or a map with the address highlighted.

The **MapPath service** retrieves a map displaying the shortest path between 2 points. This service takes an address as origin or integrates coordinates provided by the GPS.

The **Route service** also generates the shortest path between 2 points but will retrieve route direction instead of a map.

These three services will be implemented in the prototype. The following services will be implemented in the future:

- The **point of interest (POI) service** shows, for instance, restaurants, bus stops or museums on a map.
- The **event of interest (EOI) service** shows on a map the location of a specific event. The system could tell if a cultural event is taking place somewhere in the city and show the location on a map. If the user is an impaired person, the system will provide route instructions.
- The **proximity service** compares an origin to multiple destinations and determines which of the destinations is the closest to the origin. The system could then show the nearest restaurant from the user's location for instance.
- The **allocation area service** display on a map the area that could be traversed during a certain time from an origin. This service can also display the area locate at a certain distance of an origin.

The proximity and allocation area analysis are two analyses enable by the GIS engine. The following services are more specific to the application developed for the blind users:

- The **Compass Service** handles the user's bearing. Before sending a route instruction to a blind user, we need to know the initial direction he is facing. To do so, a compass is embedded in the device to determine the direction. Knowing their intended route, we can generate a direction to follow and compare it to the user's one. The system will then give instructions to correct his bearing.
- The innovative **Obstacle Service** checks if there is any obstacle on the path the user is taking. If so, instructions to avoid the obstacle are provided to the user.
- The **Tracking Service** maintains knowledge of the current location. This service enables to refresh the different analysis and adapted the response to the user's pace. This is a major service, which will enable to match the route instructions to the user's location. In the case of a sighted user, the system can send the full set of instructions from the starting point to the destination. The user will then follow them at his pace. In the case of a blind user, providing the full set of instructions on a speech format is not acceptable. The system has to follow the user's pace and to give the route instructions in accordance with the path he is taking. This also entailed to communicate the information regarding potential obstacles at the right time.
- The **management area** enables the creation of new accounts and the management of the existed ones. This area let the administrator specify new location of a component if we are in a distributed environment. The management area won't be integrated to the prototype for the moment. This area has to be customised for the client of the future application. However, basic management services will be

developed as an independent module. These services include the management of users' accounts.

2.1 The Class Diagram

The diagram in Figure 3 shows the relationships between the components of the navigation system.

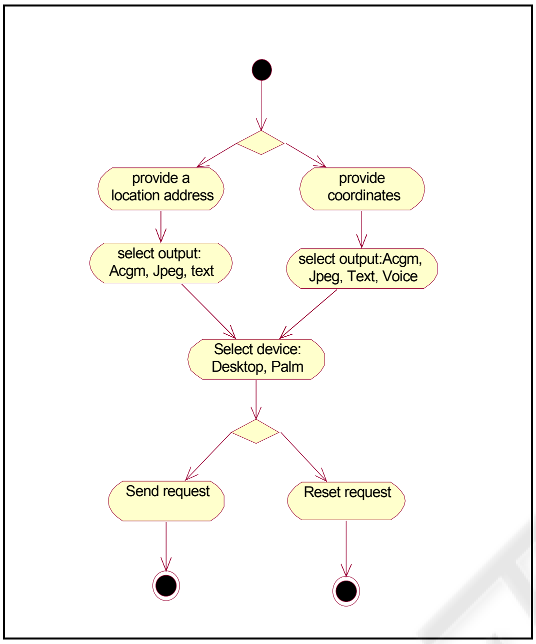

Figure 3: Activity Diagram of the Location Service.

The user interacts with the system through a device. He or she expresses a request that is the interface for the GIS services. Once the request generated, it has got all the information to call the required service. The services manager provides information about the different services e.g. their location. This will be very useful in a distributed environment. Once the request is processed, a response will be generated and send to the user in a suitable format. This response enables session tracking. If the connection breaks, the previous result generated can be retrieved when the user logs on again and saves him from building a new request.

2.2 Location Service

The activity diagram in Figure 3 shows the different options offered within the location service.

For the moment the user's got only two device options: desktop or palm. The screen size of these devices is hard-coded but the class exists and can therefore be used to extend this choice. The final client-side application will send the user's device profile to the server. The sequence diagram in Figure 5 represents the interactions between a user and the components of the system when an address is provided to the location service. Location Service checks whether more than one address match the given location and offers a list of addresses to select. If the location is requested form coordinates, the system will have to assign a street to the coordinates given. This process involves the GeoMedia Network component. A network is built over the street feature. This network is made up of edges and nodes. So that when a coordinates are assigned to a street, it is first assigned to the closest edge of the network and the system will then identify the corresponding street.

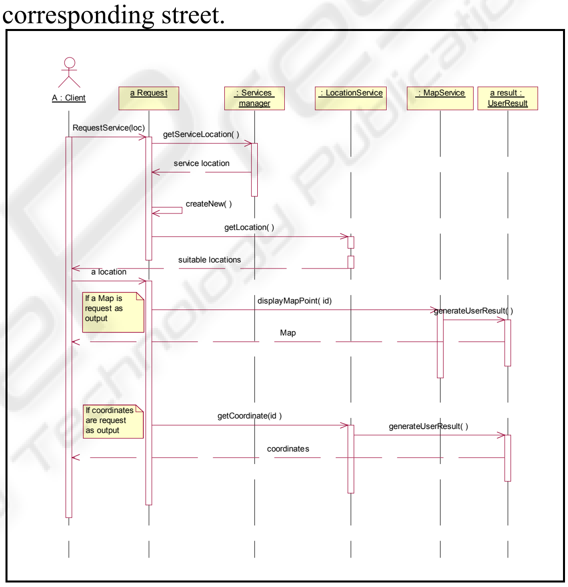

Figure 4: Sequence Diagram of the MapPath Service.

2.3 MapPath Service

Once the location of the origin and destination point is defined, Route Service generates the shortest path. The path is then sent to MapPath Service. The path of the generated map is contained in a string and sent to UserResult to build the result.

2.4 Route Service

The Route Service performs a shortest path analysis. Route direction are then generated and sent back to the request. The sequence diagram below shows the interaction between the components involved for this service.

After performing the shortest path analysis, the system checks if there is any obstacle on the path. If so the route instruction is customised.

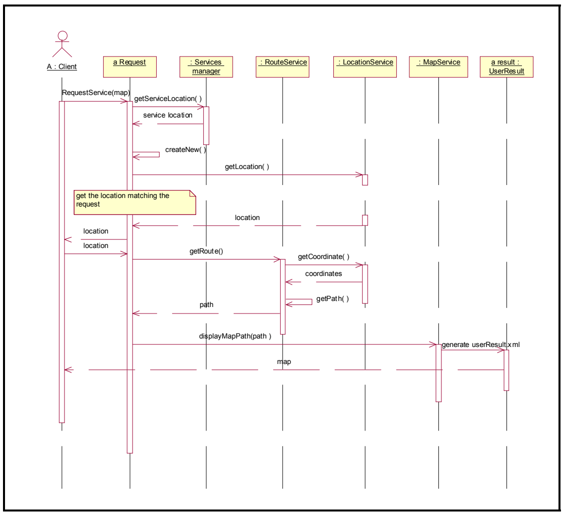

Figure 5: Sequence Diagram of the Route Service.

2.5 The Architecture and Framework

GeoMedia's architecture is based upon the Microsoft's Component Object Model (COM) technologies, therefore it seems suitable to develop the application using the Microsoft .Net Framework. Moreover, the .Net Framework provides good facilities to develop Web services. Indeed, the system is intended to be designed as a Web service in the future. The .Net framework support different languages: VB, C# and C++. ASP.Net with Visual basic seemed to be the most appropriate language to develop the system in a minimum of time, as Intergraph used VBScript in its programming documentation.

Microsoft also provides several free development tools for mobile and embedded applications under their .NET framework, such as the Microsoft Mobile Internet Toolkit (MMIT). MMIT adopted Wireless Markup Languages and compact HTML (cHTML), which can be applied for mobile devices. After thought, this toolkit won't be used here, as we prefer the more generic XML and Extensible Stylesheet Language Transformations (XSLT) approach. Because the presentation code and business logic of the application can be separated, the system will be more flexible, more efficient and more manageable. Indeed, the first prototype will be web-based, the user connecting himself to an URL, but the final system will be an application on the handheld device that makes itself the request to the server. The following schema shows communications within the system.

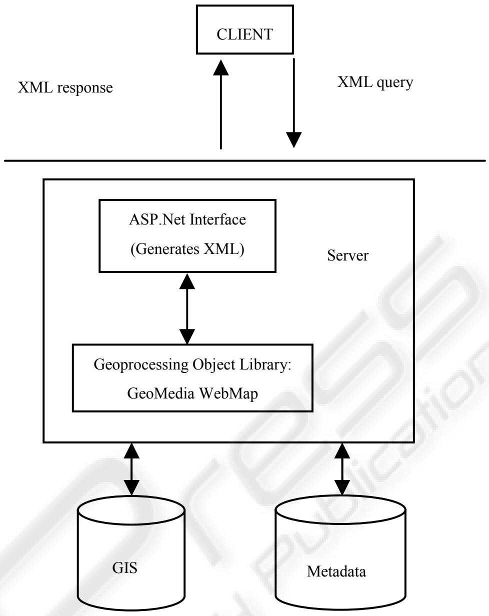

Figure 6: Communications within the system.

Communications between client and server (Figure 6) are entirely made up of XML messages. XML is an efficient communication way through the wireless network. The application takes spatial queries in XML format, answer the query and sends the result back to the calling application by way of XML.

XSLT handle transformations between XML and HTML or WML. The application calling the service will send the profile of the device used. The response will be then translated in a suitable format for this device.

2.6 The Speech Interface

The .NET Speech Platform provides a development and deployment environment for speech-enabled Web applications. The Microsoft .Net Speech SDK is built around a newly emerging standard: Speech Application Tags (SALT). SALT has been submitted to the World Wide Web Consortium (W3C) for adoption as a standard for telephony and multi-modal applications, which incorporate speech-enabled elements within a visual Web interface.

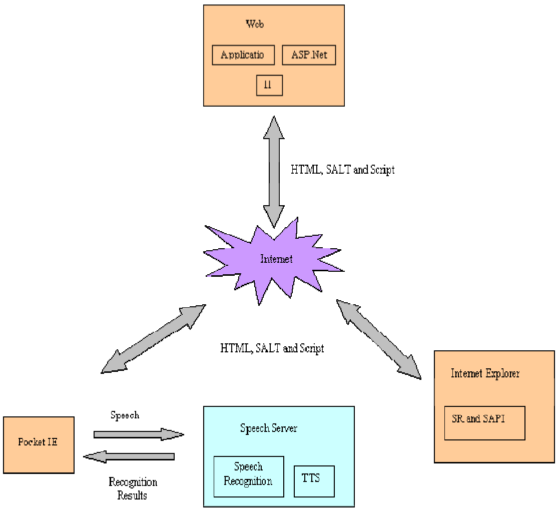

Figure 7: The speech interface.

Figure 7 provides the details of the Speech Interface used in the system development. Speech Application Language Tags (SALT) are a lightweight set of extensions to existing markup languages, in particular HTML and XHTML. It consists of a small set of XML elements, with associated attributes and DOM object properties, events and methods, which apply a speech interface to web pages. SALT enables multi-modal and telephony access to information, applications and Web services from PCs, telephones, tablet PCs and wireless personal digital assistants (PDAs).
The SDK provides a suite of four development tools for use within the Visual Studio .NET development environment: the Grammar Editor, Prompt Editor, ASP.NET Speech Control Editor, and the Speech Debugging Console.

- **The Grammar Editor** is a graphical grammar file editor. Use the Grammar Editor to create grammar files, which are then bound to a QA or Command control. The Grammar Editor also validates grammar files, verifying that the files contain valid XML code, and that they are compliant with the W3C Speech Recognition Grammar Specification V. 1.0, without building the entire application.
- The **Prompt Editor** is a data entry and edit tool for prompt databases. Use it to create a prompt database containing recording scripts, .wav files, and descriptive and tracking data for each prompt. It includes the Prompt Validate Tool, which checks prompt coverage, and allows testing of extractions in sample combinations. The Prompt Editor includes a graphical Wave Editor to customize .wav files. Use the Wave Editor to display the wave-form, edit word boundaries, copy and paste individual sound segments within and across .wav files, and play the edited .wav files.

As the application is based on an XML interface, ASP.NET Speech Control Editor won't be used.
The Speech Server provides text-to-speech (TTS) and speech recognition resources for telephony and PocketPC clients. The Speech Server receives speech and returns recognition results, and receives marked up text and returns speech.
In the first scenario, the client is Microsoft Internet Explorer with the Microsoft Internet Explorer Speech Add-in installed. The Speech Add-in implements SALT functionality using a prompt engine, text-to-speech (TTS) engine, and a speech recognition (SR) engine. Applications are developed with the .NET Speech SDK and posted on the Web Server. The Web Server exchanges HTML, SALT, and script with the Speech Add-in on the desktop. Speech recognition occurs on the desktop. Multi-modal applications with desktop clients can be deployed using only the .NET Speech SDK.
In the second scenario, the client is pocket Internet Explorer with a Speech Add-in. The Web Server sends HTML, SALT, and Script to the Pocket PC.

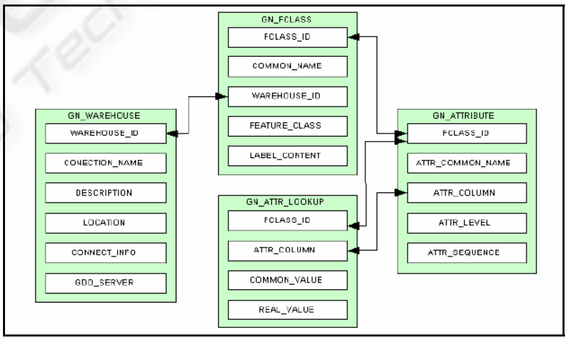

Figure 8: Structure of the feature metadata.

The Pocket PC sends a compressed representation of the audio and a pointer to the recognition grammar to the Speech Server that performs recognition and returns results to the PocketPC.

2.7 The Network

The wireless-based navigation information system will be based on a WiFi (Wireless Fidelity) network. A WiFi network is thought to be the best possible enabling technology to provide a real-time, stable, fast communication channel. The WiFi network will offer the following advantages: It's fast (11Mbps), reliable, and it has a long range (1,000 ft in open areas and 250ft in closed areas).

2.8 Metadata

Metadata are formal descriptions of data. They are very useful to enable the process of search and discovery over distributed archives. We also need metadata to determine whether a dataset, once discovered, will satisfy the user's requirements. The following diagram in Figure 8 shows the table structure of the feature metadata.

The meta-database is used to define feature classes that can be directly queried by the user through the XML interface. For example, when the user is looking for restaurants, the metadata enable to identify the source warehouse where the feature comes from, the table name and other attributes. Indeed, the table name and source warehouse may be unrelated to the feature name. This is actually the case for the restaurants as they are references as "Restaurants" in the GIS.

2.9 System Development

To be successfully driven by and deliver spoken instructions and maps to a mobile device, based on user requirements, in this case a hand held personal digital assistant (PDA) device, equipped with onboard GPS capability.

The delivered spoken instructions and maps would provide navigation support based on a route derived on the system server. The navigation support would be automatically updated based on the current position of the device, although no GIS software or map data need be installed in the device itself.

The application will be designed to be "Web Enabled" taking into account the .net environment. If possible this may provide a way of using the application on a suitable mobile phone, via the web.

It is anticipated that the software produced from this research study could be used to provide mobile location information, whenever, and wherever it is required.

This project will attempt to address the following problem areas that are associated with the delivery of spoken instructions and map images to mobile devices.

- Speed
    - Spoken instructions and images must be delivered quickly enough between client and server and vice versa. This may be difficult due to limited bandwidth.
- Data Integrity
    - Data will be delivered to devices in small packets. These must be successfully received, in order to build a recognizable image.
- Speech and image Quality
    - The speech and images received must be meaningful to the user, but this must take into account the size/resolution of the display screen.
- Relevant Content
    - Data delivered must be relevant to the user, as we are dealing with a small screen size. This must be taken into account before data is delivered.

2.10 Design

The system design will be completed using UML (Unified Modeling Language). This will produce a series of diagrams from which objects that will be required to build the system will be identified. Pseudo code may also be created at this stage, which will be used in the implementation of the system.

2.11 Implementation

The system will be implemented by following the UML design produced at the design stage. The system will be specifically implemented using Microsoft .net and the C# programming language.

2.12 Testing

Two groups of visually challenged users have agreed to test the system in Hoylake, near Liverpool. This is however the final testing stage of the project testing stage, making it ready for a final "sign off" as a finished product. Testing will however be carried out in collaboration with RNIB, on a constant basis as part of the implementation stage, in order to ensure that a complete, robust and useable piece of software has been produced.

3 CONCLUSION

Current information models do not contain the data visually challenged users need for successful navigation. Previous research recognises a need to develop a new navigation system to serve the needs of visually challenged users. To be successful, the new navigation system must provide data that visually challenged users normally find useful. Such unconventional data includes tactile, olfactory and auditory data. Contemporary navigation systems are based on an information model that uses tangible topographical features found in the micro-environment. The navigation support system described in this paper uses an enriched information model that extends conventional data by incorporating the unconventional data described above. Such data has never before been provided by a digital system. To achieve this, a major data collection effort has been undertaken to develop a new data base containing micro-data describing the case study area. Digital maps of the area have been developed for use on the navigation server. Operating via the web will ensure easy access to navigation support via a speech-driven multimodal interface. The system will provide location-based information to clients roaming freely in a wireless-enabled urban area via HTTP. Geographic spatial analyses will be carried out on a GeoMedia professional GIS-based navigation server. Not all visually challenged users have the same degree of visual impairment. The system described here will provide mechanisms for providing information appropriate to each user's requirements. Given that urban streets are filled with a wide variety of people and objects, the system provides opportunities for pedestrian users to record obstructions and changing topographical features. Information added to the database will be immediately available to other users in the vicinity. The system goes some considerable way towards overcoming the shortcomings of conventional navigation systems by providing services and facilities that better match the needs of visually challenged pedestrians in the urban environment.

REFERENCES

Blenkhorn, P. and Evans, D.G., 1997. *"A system for enabling blind people to identify landmarks: the sound buoy."* IEEE Trans. on Rehab. Eng. 5, 3, 276-278.

Brabyn, J., Crandall, W., and Gerry, W., 1993. *"Talking signs: a remote signage solution for the blind, visually impaired and reading disabled."* Proc. 15th Annual Int. Conf., IEEE Eng. in Medicine and Biology Society, 1309-1310.

Francis, H., 1997 *A Database Design for a GIS-based Relational Database for Tactile Mapping: Case Study Lancaster University Campus* M.Sc. Dissertation, Department of Systems, School of Management, Lancaster University)

Fritz, S., Michel, R., Raab, A., and Strothotte, T., 1995. *"User interface design for a travel aid for blind people."* Workshop on Non-Visual Graphical User Interfaces for Blind People, Software Ergonomie, Darmstadt.

Gilden, D., 1997. *"Moving from naive to knowledgeable on the road to technology transfer."* Technology and Disability 7, 115-125.

McInerney, R., D'Allura, T., and Benn, T., 1995. *"An evaluation of talking signs: Lighthouse staff utilization."* Arlene R. Gordon Research Institute, The Lighthouse Inc., New York.

Scadden, L.A., 1997. *Technology and people with visual impairments: a 1997 update.* Technology and Disability 6, 137-145.

Motluk A, *Senses special: The art of seeing without sight,* New Scientist issue 2484, 29 January 2005,

Yoichi Takebayashi, *Multimodal Anthropomorphic Interface,* IJCAI-97 Workshop on Intelligent Multimodal Systems

Zelek John S. September 2005, *Pages 1108-1112 Vision 2005 - Proceedings of the International Congress* held between 4 and 7 April 2005 in London, UK