Web-Based Caregiver Monitoring System for Assisting Visually Impaired People

Z.H Tee, L. M. Ang, K. P. Seng, J. H. Kong, R. Lo, M. Y. Khor

***Abstract* - This paper presents a web-based caregiver monitoring system for assisting visually impaired people. The objective of this system is to assist blind and low vision people to walk around independently and safely in transportation centers by providing speech guidance on their current location and navigation information on how to move to a particular location. The system will also alert caregivers when the visually impaired person needs assistance using a web-based monitoring system.**

***Index Terms*—Caregiver, Monitoring System, Visually Impaired People, Web Based.**

I. Introduction

Visual impairment can result from damage at any time in the life cycle of human beings. Severe visual impairment leads to a person being totally blind. Less severe cases cause a person to have partial vision loss that cannot be corrected called low vision. Genetic and developmental anomalies can cause blindness from birth. Visual impairment may also occur during adulthood when many diseases and genetic patterns manifest themselves. This paper describes research to use ICT technology for e-Inclusion in public transportation systems to tap new digital opportunities for the inclusion of visually impaired people. Public transportation systems like airports, bus terminals and mass rapid transport stations would be made more accessible to this segment of society. They would be able to travel in unfamiliar locations successfully and have a workable strategy for self-familiarization within complex environments.

In current public transportation centers, a tactile strip or paving is placed on the ground for the visually impaired person to follow. These are essentially raised textured tiles which are layered on the ground surface to denote streets and other dangerous points. There are some limitations with this method. First, it requires the person to already be familiar with the environment. Second, even if the person is familiar with the environment, the person would not know when he or she has arrived at the desired location. The person has to constantly ask people along the way as to whether they have reached the correct place. Third, in changing environments and danger situations such as fire or other sources of hazards, the paths may not be passable and there are no alternative paths to safely guide them out of the danger areas.

Several researchers have proposed technological solutions using RFID and GPS technology to assist visually impaired people [1]-[3]. Amongst the assistive systems which have been reported are SESAMONET [1], iCane [2] and Drishti [3]. The SESAMONET system [1] uses RFID technology for user localization and tracking. SESAMONET use a grid of RFID tags which are burrowed in the ground around a depth of 4cm. An RFID reader is attached to a cane to obtain the tag ID as the cane moves over the tag. This information is sent to a PDA where software looks up the navigation data for the tag ID. The navigation data is converted to speech using text-to-speech synthesis. The iCane [2] system functions similarly to SESAMONET and also uses RFID technology for person localization and to store navigation data. RFID tags are placed on tactile pathways to be read by the RFID reader on the cane.

Drishti [3] which is an integrated navigation system for visually impaired people uses the Global Positioning System (GPS) and Geographical Information System (GIS) technologies. It is designed to be used within the university premises and contains a GIS dataset of the university. This contains geographically referenced information for both static and dynamic environments and is referred to as a spatial database. The spatial database is accessible through a wireless network to a wearable device that is carried by the visually impaired person. A differential GPS receiver in the wearable device determines the localization of the user. Drishti is an assistive device which is operable in dynamically changing environments and can optimize routes for navigation when there is an unforeseen obstacle in the path. Like SESAMONET, Drishti gives assistance to the user by means of speech.

Drishti may be considered as the first reliable assistive technology system which can help the navigation of visually impaired people in dynamically changing environments. However, there are two limitations with this system. First, the prototype weighs eight pounds. Second, the degradation of the RF signals inside buildings degrades the accuracy of the GPS localization. In this paper, we present a wireless assistive system using a combination of GPS, dead reckoning module (DRM) and wireless sensor network for improved localization indoors and outdoors. The system is also designed to be light in weight. An important part of the system is the web-based system where caregivers can monitor and give assistance when required. A comparison of the above discussed interactive assistive technologies can be summarized as in Table 1.

This paper is organized as follows. Section 2 gives an overview of the system. The hardware and software

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The authors are with the School of Electrical and Electronics Engineering, The University of Nottingham, Malaysia Campus, Jalan Broga, Semenyih, 43500, Selangor, Malaysia. (phone: +603-89248118 fax: +603-89248071;email:[keyx82zhi ,kezklma, kezkps ,ecy61kjh, ecy61rl, kecy7kmy]@nottingham.edu.my.

components are described in Section 3. Section 4 describes the web-based application software for the caregiver monitoring module. Section 5 concludes the paper.

Table 1. Comparison of Current Available Assistive Technology

	SmartGuide	SESAMONET	Drishti
Localization Method	RFID	RFID	Differential GPS
Localization Data Storage	Server Database	RFID Tag + Mobile Database	-
Information Source	Server Database	Replenishing PDA Mobile Database with main source in external server	GIS Database in an external server
Information Behavior	Static and Dynamic	Static and Dynamic	Static and Dynamic
Server Connectivity	Wireless Sensor Network	Any Internet Connection (Wifi / GPRS etc.)	Wifi (802.11b)
Usage	Indoor & Outdoor, Restricted Area	Indoor & Outdoor Not restricted	Outdoor only, Area Not Restricted
Device Components Used	SmartGuide Reader, Smart Guide Tracker, Wireless Sensor Network, Server, Microphone	RFID Reader Cane, RFID tag grid, Bluetooth headset, PDA, Server	DGPS Receiver, Wifi Radio, Wearable Computer, Server
Drawbacks	RFID tags needs to be predefined.	Definitive characteristic causes failure during deviations from path	Heavy, Can only operate in outdoors

II. SYSTEM OVERVIEW

Fig. 1 shows an overview of the proposed wireless intelligent assistive navigation management system (WIANMS). The system consists of three components: SmartGuide hardware devices, mesh wireless sensor network and intelligent assistive navigation management system with the web-based caregiver monitoring system.

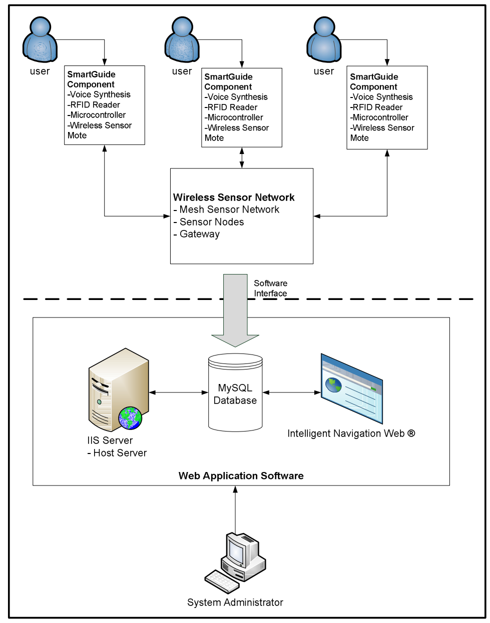

Figure 1. Overview of WIANMS.

III. HARDWARE AND SOFTWARE COMPONENTS

A. SmartGuide Device

The SmartGuide device consists of two parts. One part is attached to the cane (SmartGuide Reader) and the other part is attached to the person (SmartGuide Tracker). The two parts communicate wirelessly using Bluetooth technology. Fig. 2 shows the block diagram of the SmartGuide Reader and Tracker. Fig. 3 shows the SmartGuide Hardware Components with the RFID Tags. The SmartGuide uses various technology and sensors to achieve the localization, navigation and extraction of positioning data. A combination of RFID technology, Global Positioning System (GPS) and Dead Reckoning Module (DRM) tracking are used. The core processor for the system is a PIC Microcontroller. Bluetooth modules are used to replace the physical wires between the RFID Reader attached to the cane and the PIC microcontroller attached to the person. After the data extraction and measurement from the digital compass, GPS and DRM, the data are wirelessly transmitted to the host server via a wireless sensor mote. The host server will locate the current position and sends back the necessary speech information for user guidance and navigation.

The SmartGuide device uses the RFID tags as localization points which are located on the floor in different areas. The RFID reader reads the tag ID from the RFID tags and the DRM which consists of gyroscopes and accelerometers is utilized to complement the positioning method by providing the position between those discrete points. After the data has been sent to the central server, acknowledgement of position and localization will be done by the server from the corresponding data entry in the database. The server data is then passed to the speech module. The speech module accepts voice activated commands from the user and generates synthesized speech to inform the user of position and navigation information.

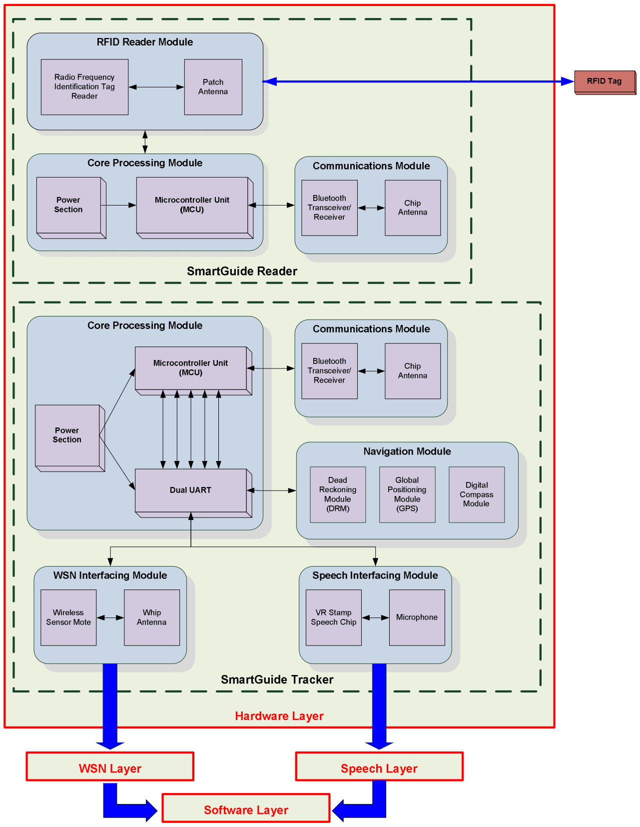

Figure 2. Block diagram of System Hardware.

Figure 3. Block diagram of SmartGuide RFID component attached to cane.

B. Wireless Sensor Network

Fig. 4 shows the architecture of the wireless sensor network (WSN). The WSN operates under a multi-hop, ad hoc and decentralized mesh networking protocol called XMesh. An XMesh network consists of spatially distributed autonomous nodes that wirelessly communicate to each other and are capable to hop the message to and from the sensor node and the base station through one or more routing nodes in between. The WSN uses the ISM band of 2.4GHz for wireless communication. Each node has been designed to support only a PAN (Personal Area Network) having a wireless coverage of 30m. All nodes use the ZigBee communication protocol to support low power transmission and reception with a low data rate (250kbps). The capability of hopping can effectively extend the radio communication range as well as reduce the power required to transmit a message.

In a mesh network, each sensor node has multiple paths back to the base station. If a node fails, the network will reconfigure itself by re-routing the message around the failed node to increase the reliability of the entire network. The WSN is self-organized and each node routes data through low traffic paths. To facilitate the shortest path algorithm, route update messages are periodically sent by all the nodes in a mesh network for the purpose of updating each other's routing tables. To accommodate the small size of the nodes, each node uses a monopole antenna. In practical use, the nodes are installed at the same specific height on the walls to fully utilize the radiation pattern. The sensor nodes are typically located 15m apart since its wireless coverage is greatly reduced due to obstacles like walls, doors and other objects.

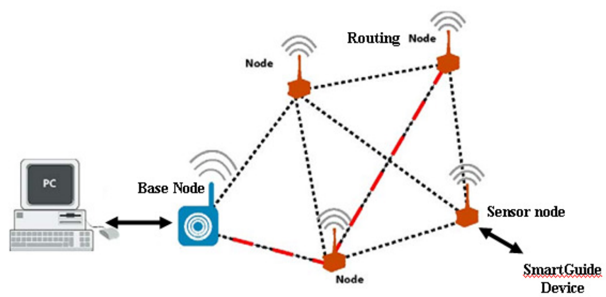

Figure 4. Wireless sensor network architecture.

C. Speech Interface

Fig. 5 shows the speech Interface. The speech module uses a VR stamp as the microcontroller. In this module, the device is programmed to recognize the commands given by the user, receive data from the server, and synthesize the speech output. The module uses speech recognition to recognize the command given by the user through the microphone. The commands will then be processed by the microcontroller. The trigger word, commands and destination data in the command table are changeable and can be customized for different users.

Speech synthesis is done by using the combination of the sound files which are stored inside the microcontroller memory. To output the corresponding instruction or assistance, the microcontroller will either playback the original file or combine two or three of the original files to form the instruction or sentence that is played through the speaker. By using this technique, the memory space requirements of the microcontroller to store the speech assistance table can be reduced. The total instruction lists that can be stored are limited by the memory spaces that store the original sound files.

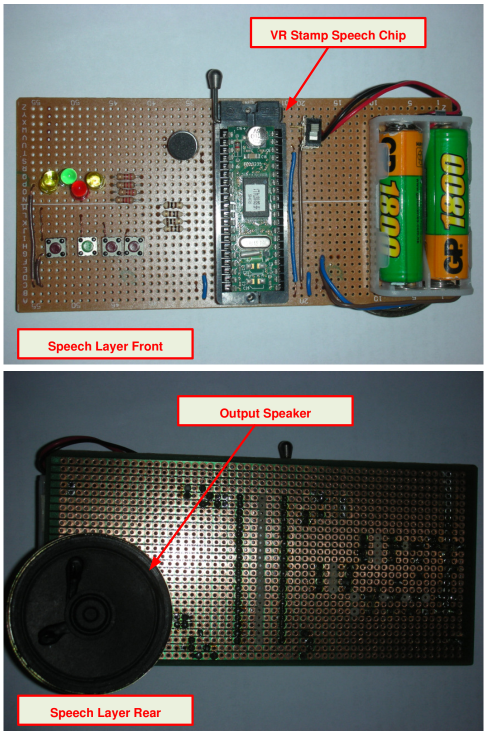

Figure 5. The speech module.

IV. WEB-BASED CAREGIVER MONITORING SYSTEM

A. *Application Software Architecture*

he web based software architecture is coded using ASP.NET with C# .NET as the supporting programming language. IntelNav Web is a web based indoor navigation system for caregiver monitoring of visually impaired people. The software is designed to run on any PC or Server running on Windows Platform. The system consists of an Internet Information Services (IIS) Server which is used to host the ASP.NET pages. A MySQL Database holds information about the user profiles and tag locations. An overview of the application software architecture is shown in Fig. 6. The database acts as the interface between the WSN and the IntelNav Web Application. The flow starts with the user giving instructions on the location he or she is heading. The WSN will provide two fields to the database which is the current user location and the requested destination. These data will be written in the "staging" table in the database which indicates that there are pending actions to be performed.

The change in database fields will then trigger the Database Watcher. The Database Watcher is a component of the IntelNav Web application where it monitors the database for a change. This component is written based on the file system watcher class which is capable of monitoring the windows' file system operations such as file changed, renamed, copied and deleted. By utilizing the file system watcher class, the database will be constantly monitored. A connection to the database will only be established once there are any navigation requests, thus saving computer processing resources and minimizing database load and maximizing the overall performance of the system. The Database Watcher component enables every single change of the database to trigger an event. This triggered event is used to indicate that there are navigation requests which are pending in the system. The IntelNav Web application will then establishes a connection to the database, obtain the required information (start tag and destination tag) and apply the search algorithm to calculate the shortest path to be travelled by the user. After the search results and distance calculations are completed, the values in the staging table are cleared and the software is put into the stand-by mode for the next set of instructions. The optimum travel path and total distance is displayed on the web application.

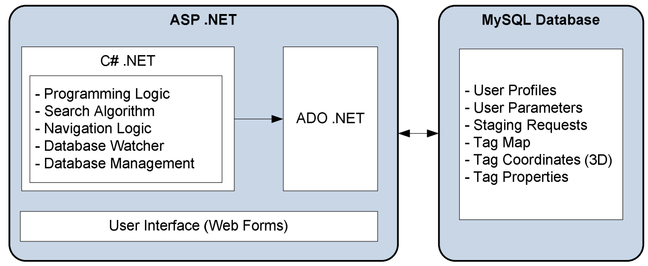

Figure 6. IntelNav Web application software architecture.

B. *Search Algorithm*

The position of all the tags acts as a localization point scattered around in an area. All these points are defined using 3D coordinates with their X, Y & Z positions stored in the database. The tag also holds information whether it is a tag that can provide access to different levels (tag positioned at stairs, escalators or elevators). The information that stores in the "tagmap" table in the database acts as a virtual map which maps out all the waypoints in a real world 3D environment. This information is essential in order for the search algorithm to be performed. Fig. 7 shows an example of the tag map when apply to real world floor plans. By convention, the origin of the 3D coordinates is set at the northwest point of the floor map. This will then give us the coordinates of points A to F respectively as shown in Fig. 7. As all the discrete points are located at the ground floor, they all have a Y coordinate of 0. The adjacent tag defined in the database is an important parameter that is required to perform the search algorithm. It allows the tag map of the system to be more complete. For instance from point C & E. In the Figure 6, because the points are not adjacent to each other, it is not possible for one to travel directly from C to E. In the real world, it would be impossible for the user to penetrate through the wall to reach point E from point C, thus the user will need to go to point D before getting to point E. A user cannot travel to a new point unless it is an adjacent point. This rule enables the travel path to be more complete when obstacles such as objects, furniture and walls come into the picture in the real world.

By joining adjacent tags of a single tag, a "virtual rail" travel path will be formed. Eventually, a complete state space and a search tree will be formed. This search tree is used by the shortest travel path search algorithm to perform calculations while the "virtual rail" will indicate the travel path to be taken. With a complete and detail tag mapping implemented via the database the performance and results of the search algorithm for navigation is guaranteed.

As all the position of the tags are mapped properly, the A* search algorithm is chosen as the backbone for the system's search algorithm. In the current scenario, the algorithm is optimal (cost to the destination tag is never overestimated) and complete (all the tags and its positions are known) making it the best choice which minimizes the total estimated solution cost. The algorithm is enhanced further so that it will be able to perform search in a 3D environment as typical buildings consists of multiple floors. [5] The A* is a form of informed heuristic search that obtains the cheapest path from the current stage to the goal. The heuristic cost function is defined as: $f(n) = g(n) + h(n)$, where $g(n)$ is the path cost (total distance travelled), and $h(n)$ is the straight-line distance from tag n to the goal. For instance if a user request to travel from the main door (point A) to the telephone (point F), the shortest travel path using the A* algorithm would be A -> D -> F. The search algorithm will check on the current tag (point A) and all its adjacent tags (in this case the adjacent tags will be B,C and D). The algorithm will then apply the heuristic function calculation and expand the nearest path as the one with the smallest heuristic distance (in this case it will be D). Similarly, the algorithm will repeat itself by exploring all the adjacent tags of the subsequent state and perform the heuristic calculation to decide which tag to expand until it reaches the goal state. All the expanded tags will form the shortest path to the destination tag requested. The 3D A* search comes into action when the destination requested is not on the same floor as the current position of the user. The algorithm will perform a search to locate the nearest gateway that provides access to different floors, in this case, stairs, escalators or elevator. The system will then provide the user navigation either up or down to the appropriate floor. The search will then continue to guide the user from the particular exit point of the gateway till the final destination which is now on the same floor.

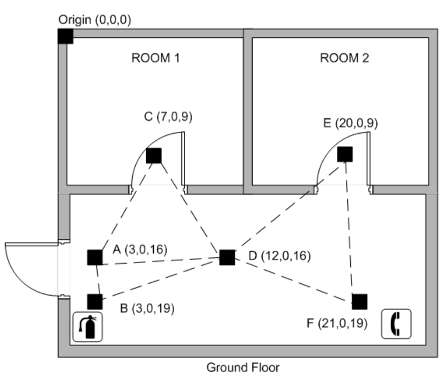

Figure 7. Example of a tag map applied to floor plan.

C. *IntelNav Web Application*

IntelNav Web is a complete web base software solution that provides not only the search path algorithm and the navigation functionality, but also the overall administration of the system, such as user management and tag map management. The web application is shown in Fig. 8 & 9. Functions can be access via the buttons on the Main Page.

The On/Off button toggles the application on and off. The browse button on the main page lets the user specify the path where the MySQL database is installed. This is used for the Database Watcher Component, where the specified directory (the database) is monitored in the background. The plan view button displays the floor plan and the tag positions on screen. The database management page and the user management page are used by the caregiver for system administrator purpose. If changes are required for the parameters of the tags such as new tags to be added or details of tags to be edited, the database management page can provide quick access for altering the database. New users can be added to the database directly using the user management page. The main page also includes a simulator which enables offline simulation of the search path selected by the user which is used for algorithm refining and debugging purposes.

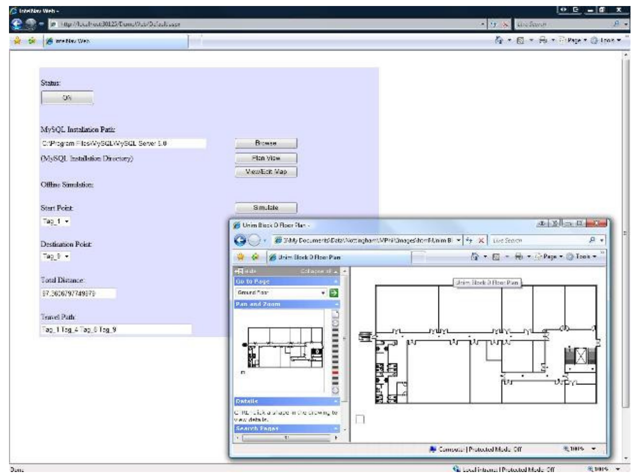

Figure 8. IntelNav Web Main Page & Floor Plan

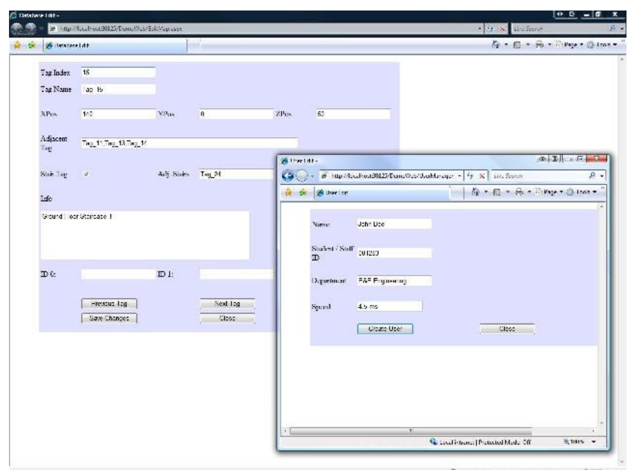

Figure 9. Database and User Management Page

V. CONCLUSIONS

We have presented a web based intelligent assistive navigation management system. RFID tags planned in the infrastructure monitors the location of the users while relaying information to and fro via the tags in the wireless sensor network to the intelligent assistive navigation management system. The web based system enables the caregiver or the system administrator to access and manage the system remotely with ease. The wireless sensor network is designed to be very low-power and fault tolerant by using a mesh network topology. Experiments carried out indicate that the wireless sensor network has minimal delay in data relaying even with walls and obstacles, thus it is concluded the system would work reliably in indoor environments. In the future, we plan to implement the system in all the buildings in the university.

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