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A Remote Vision Guidance System for Visually Impaired Pedestrians

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This paper presents research and development work on a novel system with a view of developing a navigation system for the guidance of visually impaired pedestrians. The prime aim of the new developed system is to enhance the mobility of visually impaired pedestrians using remote guidance provided by sighted person. However, the system can be used in many other applications. The system implementation is based on the integration of the Global Positioning System (GPS), Geographical Information System (GIS) database and a remote vision facility over the third generation (3G) of mobile networks, providing a technological platform enabling visually impaired pedestrians to be guided remotely by a sighted guide.

KEY WORDS

1. GPS. 2. GIS. 3. 3G. 4. Visually Impaired Pedestrians.

1. INTRODUCTION. Wireless communications technologies have been substantially developed during the last two decades; what might have seemed a dream then, nowadays is the reality. Today the Global Positioning System (GPS) can locate you anywhere on the globe with very high accuracy. Mobile communications keep you in contact while you are roaming from one place to another and the third generation (3G) mobile networks can even provide high data rate services such as video calling. These are only some examples from many applications of wireless technology. The implementation of many applications is based on the integration of several different technologies. A very good example of the integration is the vehicle tracking system (Elliott, 1996) enabling users to track vehicles remotely on their personal computers using a digital map. This system integrates mobile networks technologies and Geographical Information Systems (GIS) in conjunction with the GPS. Based on the tracking system idea, a new system has been designed by integrating GPS, 3G mobile technology and GIS. The new system enables remote tracking and guidance based on the GPS location and the live video feed. The initial goal of the system is to be used to navigate visually impaired people. Moreover, such a system can also be used for unmanned vehicle guidance, the guidance of fire fighters, police, in battle field operations as well as in other applications that need both video imagery and GPS location data (Hunaiti, 2004a).

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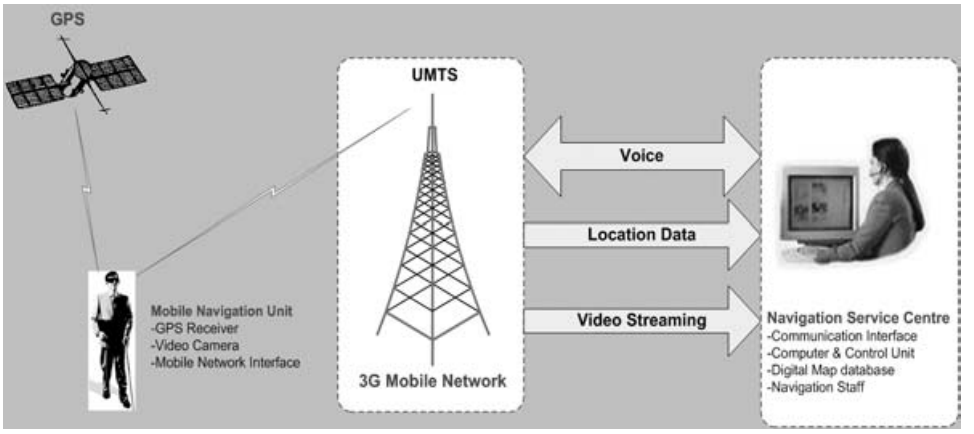


Figure 1. System Components.

2. SYSTEM ARCHITECTURE. Visually impaired pedestrians experience difficulties in acquiring the information concerning both the route of a proposed journey and about obstacles upon it. Unlike sighted people they cannot readily access information sources such as maps and timetables; neither can they avoid obstacles in their path (Petrie, 1997). A remote sighted guide would help them compensate for this lack of information. Such a system would assist them to access the wider environment and make their lives much easier. The Remote Vision Guidance System for Visually Impaired Pedestrians is aimed to increase the mobility of visually impaired pedestrians via remote guidance by a sighted person. As illustrated in Figure 1, the system will be implemented by integrating three main technologies: Global Positioning System (GPS), Geographical Information System (GIS) database and digital video streaming over 3rd Generation (3G) mobile networks. The functional components of the navigation system are accommodated into two terminals: Mobile Navigation Unit (MNU) that is located at the remote site of the visually impaired pedestrian (the user) and the stationary Navigation Service Centre (NSC), at the site of a sighted person (the guide). The MNU includes a digital video camera, a GPS receiver and a mobile network interface. This is a mobile terminal with its components contained in a wearable vest that allows for hands-free use. The NSC is a number of work stations, each containing a GIS database and a display unit to display the video image and the user's location on a digital map; these are the input information used by the sighted guide to provide the guidance service. The NSC is designed as a national or local centre, from where trained members of staff provide the guidance service. Navigation information includes real-time transmission of the video image, GPS data and voice. This information will be transmitted between the NSC and the MNU over the 3G mobile communication networks (Balachandran, 1995 and Hunaiti, 2003 and Garaj, 2003).

3. OPERATIONAL CONCEPT. The system is envisaged to operate as follows. Before embarking on the journey, the traveler uses the MNU to contact the

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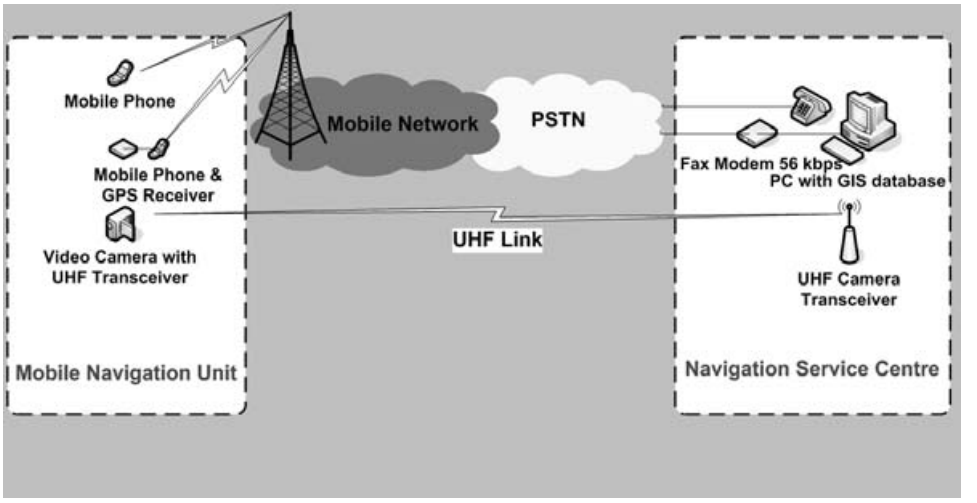


Figure 2. System Pre-prototype.

guide and request navigation assistance. When the link is established, the integrated video camera starts capturing the video image of the environment ahead of the user, while the built-in GPS receiver fixes the user's position. The system simultaneously transmits both inputs to the guide's terminal. The computer in the guide's terminal matches the GPS data with the GIS database and determines the user's position on the corresponding digital map. The received video feed and digital map are presented on the display of the guide's terminal. Following the system initialization, the user supplies the details of the required assistance to the guide, which normally includes the location of the desired travel destination. Based on the current location of the user, as determined by the GPS, and the given travel destination, the guide uses the system's GIS module to determine the optimal travel route. As the user sets out on the journey and changes location, the video and the GPS inputs are continuously updated. The guide interprets the received information and verbally communicates the navigational instructions to the user (Garaj, 2003 and Hunaiti, 2004b).

4. SYSTEM PRE-PROTOTYPE. A pre-prototype of the system (see Figure 2.) was initially established in order to test and evaluate the effectiveness in aiding the mobility of visually impaired pedestrians, with real users. Both the system main terminals, the NMU and the NSC, were constructed using off-the-shelf hardware and software. The system preprototype was tested using the existing 2G (GSM) mobile network. A communication link was established for GPS positioning data transmission, where a mobile phone linked with a GPS receiver sends the positional data to a stationary computer. The MNU was formed from an Ericsson mobile phone (GS 18) with built-in modem linked to a Motorola Oncore GPS receiver, and the NSC was formed from a stationary terminal consisting of a personal computer with a 56 Kbps modem and GIS digital map for Brunel University campus, whereby the positional data is transmitted over the mobile network and the Public Switched Telephone Network (PSTN) and plotted on digital map.

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Positional data was successfully sent using a circuit switching channel mode with a baud rate of 9·6 Kbps. Another similar communication channel was established and used as voice communication channel between the visually impaired user and the remote sighted guide. As the 2G link is only suitable for low bit-rate data transmission, this limitation inhibits the application of a GSM-based data link in a navigation system as it is not possible to achieve real-time video transmission of the desired quality sufficient to provide guidance for the visually impaired. A separate Ultra High Frequency (UHF) channel was therefore established for real-time video transmission between the NMU and the NSC (Hunaiti, 2004b). Initial evaluation trial has been carried out with the system pre-prototype being the secondary mobility aid, to help a visually impaired trial participant navigate. It was proven that the system was vital to increase the mobility of the blind participant when he was travelling in the unfamiliar environment (Garaj, 2003).

5. SYSTEM DESIGN. Since the initial evaluation has shown the system to be useful, studies have been extended to design the system components suitable with visually impaired user requirements, as well as meeting the technical requirements, to ensure the optimal performance of the overall system. The following work has been carried out in designing the system components:

5.1. *Mobile Navigation Unit Design*. The MNU will allow the user to send the navigation information and to communicate with the NSC. In the design of the MNU two main sets of requirements were taken into account: the visually impaired user requirements and the technical requirements. The MNU has to be designed such that it can be used easily and carried by the visually impaired. On the other hand, the hardware contained in the MNU needs to be located in a way that allows the optimal performance of the system. Therefore, we chose to contain the MNU within a wearable vest. The main reason for choosing a wearable option is to allow for hands-free use. The wearability of any additional equipment enables the visually impaired pedestrian simultaneously to use traditional aids like white cane and guide dog. Figure 3 shows the proposed design for the wearable vest (Hunaiti, 2004c, Hunaiti, 2005a).

The components are placed on the vest in accordance to the results from the experiments that were conducted in the testing phase of the navigation system development and based on the suggestions adopted from other projects dealing with similar matters (Hunaiti, 2004c). The reasons for the particular placement of each of the components is as follows:

- *GPS Antenna*: The guidance system is utilizing GPS for the determination of position and tracking of visually impaired pedestrians. The GPS receiver and its external antenna are parts of the equipments of the MNU. The reception of available GPS signals is an essential feature in the use of GPS. The location of the GPS antenna is very important for achieving the best reception. To ensure this, the antenna must be mounted at the same level as the local geographical horizon. Antenna should have the full view of the sky ensuring direct line-of-sight to all visible satellites overhead. In the case of a navigation system for pedestrians, the user's body itself might block the signal reception if the antenna is not mounted at the appropriate position. The best reception of GPS signals can be achieved when the antenna is mounted on the top of the head. However,

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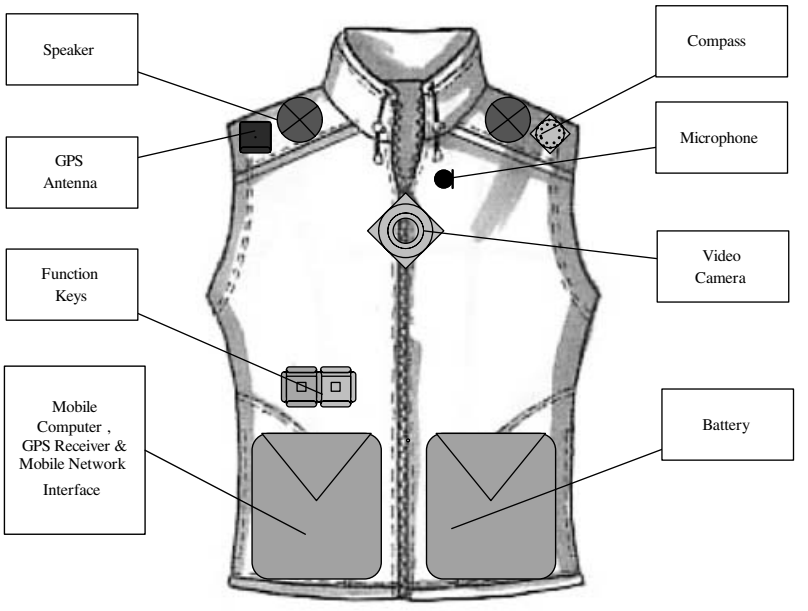


Figure 3. The Proposed Design for a Wearable Vest.

this location would not be comfortable for the user. Mounting the antenna on the user's shoulder has shown a good reception of the GPS signals and it would be more comfortable for the users (Hunaiti, 2004c).

- *Camera*: The guide has to depend on the video feed for guiding the visually impaired pedestrian. Therefore, the camera needs to be positioned in a way to enable the guide to see and detect obstacles in the area in front of the user extending vertically from ground to head-height and horizontally along the body width. The camera enables provision of information of dynamic obstacles, such as moving cars and bicycles, and information about obstacles above the waist level, such as tree branches, which cannot be avoided by using a white cane or a guide dog. In addition, the use of the camera in the navigation system has extended the range for providing the visually impaired with travel information about the surface ahead, which was very limited using the long cane (about 1 m range). The camera has to be mounted on the user's chest with an angle 15° down from the horizontal horizon. The angle of 15° represents the optimal angle enabling the guide to provide sufficient early warning for obstacles on the ground and at the head height (Hunaiti, 2005a).
- *Speakers*: In a discussion with blind and partially sighted people, as from the MoBIC (Petrie, 1997) project about the speech and sound output options, the visually impaired pedestrians were strongly against the use of headphones. They rely on various environmental sounds while they are travelling, therefore the use of the headphones will block out the environmental sounds. In the new system the location of the speakers will be on the shoulders, which will allow them to hear the navigational instructions as well as the environmental sounds.
- *Microphone*: The microphone has to be placed close to the sound source, which allows the pickup of the visually impaired pedestrian's speech while

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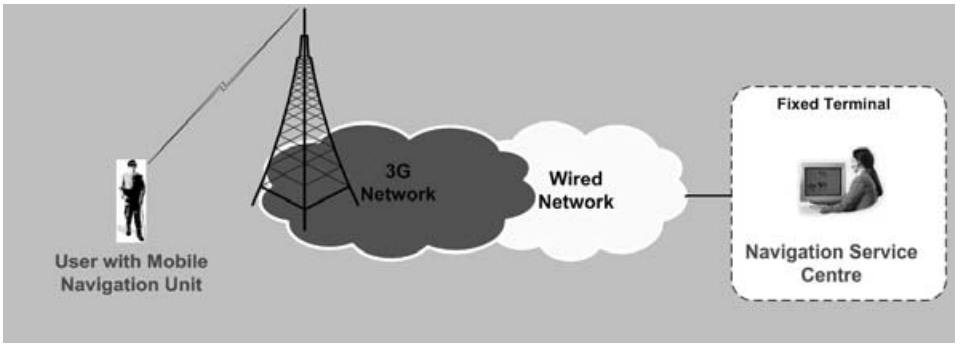


Figure 4. Proposed Communication Link.

simultaneously avoiding any significant influence from the surrounding space. Therefore, the microphone has been placed in the top part of the vest close to the mouth (Hunaiti, 2004c).

- *Function Keys*: The participants in the MoBIC (Petrie, 1997) project demanded that the number of keys should be as few as possible and easy to distinguish from one another. The function keys' location has been chosen to be near the pocket which can be considered as easy to access. In the implementation phase the number of the function keys will be kept as few as possible.
- *Compass*: An electronic compass can be used as an additional navigation sensor. Heading from the compass helps the guide to provide the visually impaired pedestrian with directional instruction such as, turn left or right. The best performing compass has to be mounted on the shoulder for this purpose (Randell, 2003).
- *Communication Interface*: The communication interface which will be used to link the MNU with mobile network should follow privileging standard, i.e. ITU-T H.324/M for 3G mobile networks. Following this standard allows the user to connect with different service providers (Hunaiti, 2004c).
- *Additional Requirements for MNU*: As suggested by participants in the MoBIC (Petrie, 1997) project, the following points should take into account:
  - The wearable vest should be weatherproof to allow its use in rain or snow.
  - The vest should include a compass for orientation.
  - The vest should have low power alert, to indicate to the user when the battery gets low.
  - The battery charging system should be designed to be used by visually impaired pedestrians.

5.2. *Communication Link Design.* The outcome from the previous study on the performance of the mobile link (Hunaiti, 2004c and Hunaiti, 2005b) indicated that the mobile link might suffer from delay, packet losses, link outages and variation in the throughput. This is due to the nature of the radio channel, high disturbances, fading, interference, congestion, handover etc. Most of the problems occur in the air interface (between the mobile terminal and base station). There is a possibility to reduce the impact of the mobile link, by using the 3G link only on the side requiring

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mobility i.e. the visually impaired side, and using another technology in the NSC site such as fibre optic cables (Hunaiti, 2005c). An illustration for a possible solution is shown in Figure 4. This will guarantee the establishment of a navigation system with the required mobility operation and ensures the best achievable link performance. In addition, the proposed channel can be easily implemented as an autonomous communication system using the available 3G mobile network infrastructure, which would help in saving the cost of running the system, wherever the 3G coverage is available.

5.3. *Navigation Service Centre Design*. The navigation service centre is a network of people and equipment that ensures the smooth operation of guiding visually impaired pedestrians. The simple form of the NSC consists of a personal computer (guide terminal) with required facility, both software and hardware, and trained sighted guide. However, the NSC can be expanded to become a local or national service centre (Elliott, 1996).

6. CONCLUSION.

This paper has presented the work done on developing a new navigation aids system for guiding visually impaired pedestrians, by a remote sighted guide. System components, the operational concept, system pre-prototype and work on designing major components, have been described. The system will be very vital to aid visually impaired people and ease their mobility.

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