Interface Design for a Remote Guidance System for the Blind: Using Dual-Screen Displays

A thesis submitted for the degree of Doctor of Philosophy

By

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This Thesis is Dedicated to

My Father Soul, My

Mother,

My Brothers, My Sisters,

My Nephews and Nieces

ABSTRACT

The mobility for the visually impaired people is one of the main challenges that researchers are still facing around the world. Although some projects have been conducted to improve the mobility of visually impaired people, further research is still needed. One of these projects is Brunel Remote Guidance System (BRGS). BRGS is aimed to assist visually impaired users in avoiding obstacles and reaching their destinations safely by providing online instructions via a remote sighted guide.

This study comes as continuation of the development process of BRGS; the main aim that has been achieved of this research is the optimisation of the interface design for the system guide terminal. This helps the sighted guide to assist the VIUs to avoid obstacles safely and comfortably in the micro-navigation, as well as to keep them on the right track to reach their destination in the macro-navigation.

After using the content analysis, the performance factors and their assessments method were identified in each BRGS' element, which concluded that there is a lack of research on the guide terminal setup and the assessment method for the sighted guide performance. Furthermore, there are no model to assist the sighted guide performance and two-screen displays used in the literature review and similar projects.

A model was designed as a platform to conduct the evaluation on sighted guide performance. Based on this model, the computer-based simulation was established and tested, which made the simulation is ready for next task; the evaluation of the sighted guide performance.

The conducted study determined the effects of the two-screen displays on the recognition performance of the 80 participants in the guide terminal. The performance was measured with the context of four different resolution conditions. The study was based on a simulation technique, which is consisted of two key performance elements in order to examine the sighted guide performance; the macro-navigation element and the micro-navigation element. The results show that the two-screen displays have an effect on the performance of the sighted guide. The optimum setup for the two-screen displays for the guide terminal consisted of a big digital map screen display (4CIF [704p x 576p]) and a small video image screen display (CIF [352p x 288p]), which one of the four different resolutions. This interface design has been recommended as a final setup in the guide terminal.

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CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

Current lifestyle and activities require individuals to travel and change locations in order to be mobile. Mobility is defined by one's ability to change place safely, independently and to avoid obstacles by corrective detection, in order to reach the destination and monitor one's position in relation to the environment. However, people with mobility limitations have a significantly lower quality of life in comparison to those who are mobile. There are many mobility limitations; one of these mobility limitations is related to vision. Sense of vision limitations affect people's mobility by having limited access of information related to the travel environment and obstacle detection.

A number of methods to aid the mobility of the visually impaired people have been proposed over time. Nevertheless, a sufficient response to their mobility needs has not yet been offered. Only three methods are established and applied widely, which are guidance by use of a long cane, guide dog assistance, and a sighted human guide. All of these conventional methods of navigation have been used for centuries (Garaj, 2006). Many new technological aids have been used to help people travel with a greater degree of psychological comfort and independence.

The systems that used these new technologies are based on Global Positioning System (GPS) and Global Information System (GIS), which are different types of navigation devices and have been used in different areas of human activity, such as the navigation of vehicles, vessels and pedestrians. Additionally, using GPS and GIS during pedestrian navigation helped researchers to develop new navigation aids to assist the mobility of the visually impaired pedestrian. These systems are meant to provide users with an additional degree of freedom by allowing them to travel on foot safely and independently (Hunaiti et al., 2006a). One of these systems is the Brunel Remote Guidance System (BRGS), which aims to help Visually Impaired Users (VIUs) to navigate through familiar and unfamiliar environments and thus enhance their mobility by providing guidance via a remote sighted (human) guide to avoid obstacles and reach their destination. BRGS was designed by a navigation research team within the Centre for Electronic Systems Research at Brunel University (CESR). The system is based on integrating state of the art technology, including satellite navigation (GPS), wireless broadband, digital mapping (GIS), databases, and real-time video streaming (Garaj, 2010).

BRGS consists of two main terminals: the guide and user terminals. The guide terminal contains a Sighted Guide (SG) person, who assists the VIUs remotely, and a stationary PC. The user terminal includes VIUs and a mobile unit connected by a wireless network (e.g. 3.5G). This wireless link is used to transmit the voice communication, GPS location and video image. The video image and the digital map are displayed in two-screen displays on the guide terminal. The digital map enables the SG to track the VIUs during the journey in order to reach the destination. The video image allows the SG to assist the VIUs by describing the environment ahead. The video image is streamed from the user terminal camera.

The guide terminal in BRGS is a human-computer interaction application, defined as an interaction between the computer (i.e. two-screen displays) and the user (i.e. sighted guide). However, this kind of HCI applications is called a multitasking application for the reason that the sighted guide needs to use and operate two screen displays, which have a different task, to gain the information about the VIUs travel environment and the VIUs travel track. Using different displays at the same time in multitasking applications that are defined as a multiple displays, which is one of the most important applications that is used in the HCI. Whereby, visual displays are considered to be a link between the sighted guide and the computer, in order to present the information in an easily comprehensible visual form (i.e. sighted guide users utilise their sense of vision to monitor different displays). The multiple displays require to divide the attention between the two screens by the sighted guide, which is known as visual attention. This meant the ability of the sighted guide to operating two screens while displaying the information. This ability could evaluate the sighted guide performance in using the guide terminal in BRGS, which is important to assist the VIUs during their journey.

One of the most important elements of the BRGS is the guide terminal, which is used by the sighted guide. The performance of the sighted guide is based on providing the correct guidance and instruction to the VIUs. These guidance and instructions are highly dependent on the interface design, which is the source that the sighted guide needs to use as a means to gain the information about the travel environment of the VIUs. The sighted guide needs to divide the attention between the two screen displays to assist the VIUs to avoid obstacles by using the video image display as well as to provide the VIUs direction by use of the digital map display to reach the destination. Thus, this study aims to find out the suitable interface setup that will increase the sighted guide performance by providing the right instructions to the VIUs. Furthermore, the interface design improvement on the guide terminal works as a further step to improve specifically the BRGS and to improve the other systems that use the remote guidance systems in general.

1.2. MOTIVATION

The main motivation to conduct this project is to be involved in a society that supports and helps those people with a vision disability and works to improve their quality of life. In this project effort is spent to assist those people in becoming mobile in order to help them travel with a greater degree of psychological comfort and independence.

Further motivations, mentioned below in detail, are taken into account to improve the BRGS based on the future work that has been reported in previous studies:

- A method needs to be established in the guide terminal to reduce the problems of dividing the attention in monitoring the system guidance resources.
- As the video image is one of the main performance parameters when using the BRGS, further work should include the estimation of potential effects on the performance when including different resolutions of the video image and digital map, two inputs are placed on the guide terminal.
- BRGS needs to be improved by including a GIS mapping system, which will help the sighted guide to provide efficient information to the users. This should also support the sighted guide by providing extra information about the macro navigation of the user.

1.3. AIM AND OBJECTIVES

The main aim of this research is to optimise a suitable interface design of the guide terminal that enables the sighted guide to provide efficient guidance instructions to VIUs and to develop and improve the overall performance of the BRGS. This research works towards a solution that will help the VIUs avoid obstacles safely and comfortably in the micro-navigation, as well as to keep them on the right track to reach the their destination in the macro-navigation.

To achieve the previously mentioned aim, the research pursues five objectives, namely to:

1. Conduct a literature review covering all aspects related to the navigation systems of the visually impaired users. This will include the design and architecture of the systems. Furthermore, comprehensive literature reviews need to be carried out to identify Human Computer Interaction (HCI); including multi-tasking and multi-display applications.
2. Establish a critical analysis to detail all the BRGS performance elements and their factors, as well as to identify the assessment method for each element, in order to highlight the BRGS shortcomings relating to the guide terminal.
3. Design an arithmetical model that includes all the performance factors in the guide terminal in BRGS with their assessment methods to be a base in evaluating the sighted guide's performance in BRGS and in other remote guidance systems.
4. Identify the guide and the user requirements to establish a computer-based simulation to evaluate the sighted guide's performance as well as to find out the optimum interface setup for the guide terminal in BRGS to help in achieving the best service of the guidance process.

5. Propose the final setup of the interface design for the guide terminal in BRGS.

1.4. RESEARCH METHODOLOGY

The need for a clear path of research is important when undertaking a research project; this enables higher efficiency in research work and enables other researchers continuing the same research to effectively undertake the project in a comparable manner. This study encompasses the research means and methods selected to perform this research in respect to each subsection, and the intended outcome. The secondary research was initiated by reviewing existing secondary research materials from textbooks, provided course materials, journal publications, conference papers and existing knowledge of the related subject topics. The main aim was to gather and critically appraise relative information, strategies and existing implementations. Enabling technologies were reviewed throughout the literature, associated with the remote guidance system and human computer interaction, and a comprehensive overview of the literature was conducted with special emphasis on new materials acquired through published papers and journals.

The following primary research work conducted a content analysis in order to detail all the BRGS performance elements and factors as well as to detail the assessment method for those elements. The outcome of this study was the need to establish an efficient method to evaluate the performance of the guide terminal within the context of providing sufficient important information for the guidance process.

The second step of the primary research established a model as a platform to conduct an evaluation on sighted guide performance. The model performed as a computer simulation to evaluate the guide performance in BRGS, reflecting similar environments to real life. The methodological approach that the computer-based simulation was based on is the Waterfall System Development Life Cycle (SDLC) model (Avison & Fitzgerald, 2003). A pilot study was carried out to examine the reliability of this simulation. The final step of the primary research was conducted as an extensive simulation test in order to evaluate the effects of the two screen display on the sighted guide performance. Finally, further details of each study methodology are explained in their chapter, which helped to complete this PhD research.

1.5. CONTRIBUTION TO KNOWLEDGE

- This study comes as continuation of the development process of BRGS; the main aim that have been achieved of this research is the optimisation of the interface design for the system guide terminal that enabled the sighted guide to provide more efficient guidance instructions to Visually Impaired Users (VIUs). The guidance includes assisting the VIUs to avoid obstacles safely and comfortably in the micro-navigation, as well as to keep them on the right track to reach their destination in the macro-navigation.

- The first contribution of this research study, a content analysis was conducted, which provided further support to the literature review findings related to the lack of research done on the guide terminal. The main findings that have been concluded from the content analysis of the performance factors in BRGS are: there is no clear setup and performance assessment method for one essential part on the system (the guide terminal).
- This research study also reported an integrated model of the remote guidance system as a further contribution, which gave a solution for the shortcoming and allowed the performance assessments of the remote sighted guide to be simulated.
- The conducted study determined the effects of the two-screen displays on the recognition performance of the 80 participants in the guide terminal. The performance was measured with the context of four different resolution conditions. The study was based on a simulation technique, which is assisted of two key performance elements in order to examine the sighted guide performance; the macro-navigation element and the micro-navigation element. Where, the macro-navigation element is based on any error that is affected the right track of the VIUs in the wide-travel environment. The micro-navigation element is consisted of the micro-navigation obstacle recognition, which is based on any stationary environment hazard that located with the VIUs movement, and the micro-navigation response distance of obstacle, which is based on the ability of the sighted guide to judge the right distance to report obstacle in advance to the VIUs. The results show the two-screen displays have an effect on the performance of the sighted guide. The optimum setup for

the two-screen displays setup for the guide terminal was consisted of a big digital map screen display (4CIF [704p x 576p]) and small video image screen display (CIF [352p x 288p]). This interface design has been chosen to use as a final setup in the guide terminal, which was reported the best performance results between the other groups.

1.6. Thesis Layout

The layout of the thesis corresponds to the structure of the work, as undertaken throughout the study. Following this introductory chapter, the thesis includes five more chapters, references and appendices. A brief content description for the five chapters is presented below:

Chapter 2 provides the summary of the literature review and related works that are related to the PhD project to fully understand the main aspects.

Chapter 3 details and analyses the BRGS project elements and identifies all of the factors for each element and their assessment methods. In addition, this chapter also highlights the main shortcoming found from both this stage and the literature review stage.

Chapter 4 provides the design of the sighted guide performance model and includes the main performance factors of the guide terminal with their assessment methods. Furthermore, chapter 4 includes the procedure that was followed to build the computer-based simulation and the pilot study for the initial performance evolution.

Chapter 5 presents the method and the main outcomes of the sighted guides' performance laboratory test. This test was carried out based on the performance factors, in order to determine the optimum interface setup of the guide terminal, which will be used to improve the performance of the sighted guide to provide a better service while assisting the VIUs.

Chapter 6 concludes the project and suggests future work in order to improve the final setup and lead to a better implementation of the system.

CHAPTER 2

BACKGROUND AND LITERATURE REVIEW

2.1. MOBILITY

In recent years, the continued lack of self-contained systems that allow visually impaired individuals to navigate through familiar and unfamiliar environments has led to an increase in efforts to develop new systems and technologies for the navigation and orientation of visually impaired people (Völkel et al., 2008). These technological advancements have made the mobility of visually impaired users (VIUs) much easier, independent and safe (Hunaiti, 2005; Loomis et al., 2005). 'Mobility' is defined as the ability to move and change location (1.1). Mobility has two categories: navigation and orientation (Szeto, 2003).

Navigation comprises two tasks: the ability to reach the goal and the ability to avoid obstacles (Striemer et al., 2009). To be able to reach the goal it is necessary to know the starting point and the destination locations, and the path that one needs to follow to reach the goal. In terms of obstacle avoidance, one needs to detect an obstacle and find a clear (obstacle-free) trajectory to maintain journey. Orientation is the ability to monitor one's position in relationship to the environment (Szeto, 2003; Bradley & Dunlop, 2005).

Hence, one needs to monitor the position by establishing and actively keeping the knowledge of current location and direction in the travel environment in accordance with an established journey route (Loomis et al., 2005; Völkel & Weber, 2007). The relationship between one's position and the travel environment (surroundings) throughout the journey is recognised by objects and landmarks, such as phone boxes, bus shelters, trees, street signs, post office buildings (Caddeo et al., 2006; Hub et al., 2006). Recognition of objects and landmarks helps build one's knowledge and create a cognitive map, which is then used to create a clear route and help avoid obstacles. To be successful throughout the journey and to reach the goal, one must know where one is, the surrounding environment, where the destination lies and the best route to reach the destination.

As mentioned, navigation is based on the ability to use senses in the perception and acquisition of navigational information. The most effective sense is that of vision, which enables travellers to identify obstacles in the direct travel environment, which can help to create a route reaching the destination (Fajarnes & Garcia, 2010). The sightless or visually-impaired person has serious difficulties in navigation, due to the lack of sensory knowledge necessary to plan a route, and difficulties in detection and obstacle avoidance, which are the main tasks for navigation. Furthermore, lack of knowledge affects the processes that the visually impaired person uses to create the cognitive map (Ungar, 2000). The chief travelling difficulties for the visually impaired are localisation and environment perception, and selecting and maintaining correct heading, which are influenced by the process of orientation. The only way to assist the visually impaired to navigate is to use mobility aids.

2.2. MOBILITY AIDS

Traditionally, blind people have been assisted by a sighted guide, or specialised aids, which are utilised to compensate for their visually impairments (Hunaiti et al., 2006). However, several visual aids have been developed during recent decades that make the lives of the blind easier. Moreover, special software packages have been developed that make computers and mobile devices more friendly for the blind user (Sanchez et al., 2007). The following subsection presents an overview of the most important mobility aids for visually impaired people implemented so far. The overview includes analysis of the functionality of the aids and the benefits of their application.

2.2.1. CLASSICAL MOBILITY AIDS

Current developed aids that have been completely developed are sighted human guide, long cane and guide dog. Additionally, these are the oldest methods of assisting visually impaired people (Garaj et al., 2003; Blash and Stuckey, 1995; Whitstock et al., 1997; Farmer and Smith, 1997). All three have been in practice as long as blindness has existed; these mobility aids are regularly referred to as ‘classical’ mobility aids (Farmer & Smith, 1997).

i. Sighted Guide

The most reliable method that offers comprehensive assistance for the blind or visually impaired is the use of a sighted human guide (Farmer & Smith, 1997) . Guiding people is about giving them more useful information, usually including obstacle awareness (Rajamäki et al., 2007).

Sighted guidance is the only way to support visually impaired people through the journey with minimal limitations. However, the availability of sighted guidance accompanying the visually impaired increases the cost, especially if a guide is needed urgently (United States et al., 2004). However, the incomparable benefits of using a sighted guide compared with alternative methods are overwhelming. One of the benefits of using a sighted guide is reducing the stress levels of the visually impaired person throughout the journey, which is effected by the sight’s guidance.

Furthermore, use of a sighted guide increases obstacle recognition and hazard detection. Human guide detection range is superior to other traditional aids such as guide dogs or long canes. In addition, the success journeys using sighted guidance assistance in reaching the destination is much higher.

ii. Long Cane and Guide Dog

Long canes (Figure 2.1) and guide dogs (Figure 2.2) have more or less reached the ultimate extent of their potential development, and they are most commonly used aids by visually impaired people (Jansson, 2008; Blasch et al., 1997; Farmer & Smith, 1997). Among the advantages of using a long cane is that touching it down ahead of the next footstep provides the user with a preview of the immediate environment and detects obstacles, changes in the surface of travel and the integrity of the surface for foot placement (Blasch et al., 1997).

Sometimes, this preview extends to just ahead of the next step of the user. Longer canes can be used that increase environmental preview, which provides greater reaction time for visually impaired people. Canes and longer canes in particular, are usually lightweight, utilising materials such as fibreglass or carbon fibres, which permit a longer cane shaft without increased weight.

On the other hand, long canes have some disadvantages. The main problem is that obstacles can be detected only by direct contact with objects in the path of travel. This can be inconvenient to the visually impaired, and limits their awareness of their surroundings. The long cane cannot detect potentially dangerous obstacles overhanging the ground at heights above the waist level, which will not offer adequate protection to the upper part of the body (e.g. protecting the head against collision) (Garaj, 2006).

In addition, this device is rather inconvenient, as it requires the visually impaired pedestrian to constantly scan the small area ahead of them. Furthermore, the long cane cannot detect obstacles further than 1m (depending on the length of the cane in use). The long cane's detection distance is rather short, and is effective only in determining the features of a limited distance (Farmer & Smith, 1997).

Figure 2. 1 White cane (Whitecane, 2010)

Guide dogs are very capable guides for the blind, and the use of dogs solves some of the limitations of using long canes (e.g. guide dogs are trained to avoid obstacles overhanging the ground at heights up to the height of the human body, which cannot be detected by long canes). Furthermore, the guide dog is able to recognise an obstacle from a distance and directly lead the visually impaired person around it, giving them sufficient distance to avoid the obstacle. However, the main drawback to having a guide dog is that many blind and visually impaired people are elderly and suffer other disabilities, which makes caring for the dog difficult (United States et al., 2004). Dogs require constant attention from their owners, including regular feeding and exercising. Many blind people may be disinclined – or even fearful – to keep a dog. Moreover, guide dogs require extensive training, which can be costly, and their useful lifespan is only approximately five years (Garaj, 2006).

Figure 2. 2 Guide dogs (Guidedogs, 2010)

Long canes and guide dogs help to detect hazards. However, blind people need more information to find detours, rearrange routes, and improve reliability in the detection of obstacles, or in reaching destinations in unfamiliar places.

2.2.2. HIGH-TECH MOBILITY AIDS

Based on the technology improvements and the need to reduce the limitation of the classical mobility aids; a new mobility aids have been developed in the last decades, which are defined as a high-tech mobility aids. The main aim for these aids is to increase the mobility support on independent journey of the visually impaired. High-tech mobility aids are contained two categories of aids; electronic travel aids and electronic oriented aids. The next two sections are explained those categories in more details:

i. Electronic Travel Aids

During the last few decades, several researches developments have improved mobility aids, accordingly to available technology. Using radar and ultrasonic technologies, a new series of mobility aid devices have been designed to help blind and visually impaired people to navigate, such as electronic travel aids (ETAs) (Cesetti et al., 2010; Fajarnes & Garcia, 2010). In terms of operational principles, most ETAs operate similarly to radar systems; a laser or ultrasonic energy waves are emitted in the travel environment ahead, then the energy waves are reflected from obstacles in the path of the user and detected by a matching sensor.

Thus, the distance to the obstacle is calculated according to the time variance between emitting and receiving the energy waves. In that case, the ETA converts this input into an output signal and delivers the signal to the user through the sense of hearing, the sense of touch, or both senses simultaneously (Farmer & Smith, 1997). All ETAs are based on the same principle, but ETAs developed different functionalities. The main difference is in the type of energy waves utilised to explore the travel environments, depending on the environment exploration range and accuracy of the accessible information on the location of the detected obstacles in the travel path (Ando, 2003; Loomis & Klatzky, 2001).

However, there are some fundamental drawbacks that can be identified in all ETAs; the lack of some of the research interest in ETAs is due to their utilising ultrasonic and laser technologies (which are the basis of ETAs functionality), which are deemed to be limited in application and are not likely to yield further significant improvements. One of the user's hands will always be engaged in operating the device (Beckmann, 2004). Some ETAs cannot detect transparent obstacles, such as glass doors and bus shelters, because transparent objects do not reflect infrared light beams emitted by the built-in lasers. Moreover, while the user detects an obstacle and determines the scope of the object, user walking speed is reduced as additional time is consumed, and user-conscious effort is required. Some ETAs use audible feedback to alert the user. A drawback of audible feedback is their lack of ability to function correctly in noisy environments, as noise overshadows the aid's audio feedback. This reduces the blind person's ability to hear essential cues (Loomis et al., 2005).

ii. Electronic Orientation Aids (EOAs)

Orientation and mobility instruction will help blind people to live actively and to travel independently with confidence in familiar and unfamiliar environments (Kim, 2010; Szeto, 2004). Moreover, the orientation while travelling is achieved by identifying both person-to-object relationships and object-to-object relationships in the environment (Kim, 2010). Thus, based on the principles of orientation, research has been focused on the design and development of high-tech mobility aids within last twenty years in order to create aids capable of assisting visually impaired people while travelling. These aids, which are known as Electronic Orientation Aids (EOAs) are opening new mobility possibilities for visually impaired people. EOAs depend on the utilisation of the Global Positioning System (GPS) and the Geographic Information Systems (GIS) (Garaj, 2006).

GPS is a space-based radio navigation system developed and operated by the US Department of Defence between the 1970s and 1990s. GPS consists of three segments. The first is the Space Segment, which includes 24 satellites; each satellite broadcasts radio frequencies' ranging codes and a navigation data message. Additionally, the space segment satellites are orbiting the earth in six orbital paths (Nabhan, 2009). The second is the User Segment, which consists of a variety of radio navigation receivers, which are capable of receiving the satellite signals. The third, the Control Segment, consists of a network of monitoring and control facilities used to manage the satellite constellation and update the satellite navigation data messages. The major aim of GPS is positional and navigational information acquisition (Almasri, 2009; Navstar, 1996). GPS positioning normally requires concurrently a minimum of four satellites of the receiver. This enables the receiver to determine the three unknown parameters representing its 3D position, in addition to a fourth parameter representing the user clock error (Almasri, 2009).

Whilst the device is running, the GPS receiver captures the incoming radio signals from the GPS satellites. Depending on the signals that contain encoded information on the accurate position of the satellites in space, the distance between the GPS receiver and the satellite is calculated by the processing unit. Specific mathematical algorithms are used to calculate this distance, which determines the geographical location of the GPS receiver (Nabhan, 2009). In addition, the GIS application involves a digital geographical map and software to operate the application and a processing unit. The processing unit provides the data, which come from the geographical location of the GPS receiver (the location of the user of the device), to the GIS application. The GIS application matches this data with the digital map of the geographical area surrounding the user that is contained in the application. The location for the user is presented on the device screen, as well as different format to present the user location, such as voice message and text message (Almasri, 2009).

Based on the GPS and GIS, different types of navigation devices have been used in different areas of human activity, such as the navigation of vehicles, vessels and pedestrians. Additionally, using GPS and GIS during pedestrian navigation helped researchers to develop new navigation aids to assist the mobility of the visually impaired pedestrian. One of the earliest proposals to utilise the GPS and GIS for aiding the visually impaired people was made in 1985 by J.M. Loomis of the University of California in Santa Barbara, USA (Loomis & Klatzky, 2001). J.M. Loomis and his research team also carried out a project in which they designed, developed and tested one of the first EOA prototypes. Since the first EOA, various EOA prototypes have been designed, developed and evaluated (Loomis & Klatzky, 2001). Nevertheless, the majority of these EOA prototypes are similar to each other in terms of functionality, system architecture and user interfacing (Garaj et al., 2007).

Generally, based on the GPS and GIS, the functionality for the EOAs in a journey occurs as follows. When the visually impaired user starts a journey, the EOA is immediately activated. The GPS receiver, which is built into the EOA, starts capturing the signals from the GPS satellites in space via the antenna. Based on the information contained in the signals, the EOA's processing unit determines its current location, which is matched on the digital map by using the GIS application, which is built into EOA. The EOA location is presented to the user as a voice message by the EOA speaker. Following the determination of the starting location, the user enters the chosen location of the journey destination into the EOA utilising the EOA's keyboard. Based on this input, the processing unit establishes the journey route between the starting location of the journey and the destination by using the route-planning algorithm within the GIS application. The EOA continually updates the user's location towards the destination (Nabhan, 2009). More examples are explained in the following sections have used the EOA in their applications.

2.2.3. MOBIC (MOBILITY OF BLIND AND ELDERLY PEOPLE INTERACTING WITH COMPUTERS)

The MoBIC project existed from 1994 to 1996, supported by the Commission of the European Union (Strothotte et al., 1996; Abascal & Civit, 2001). The main aim was to increase the independent mobility of visually disabled people travelling in unknown environments. MoBIC was designed in relation to orientation and navigation aids based on technology for non-disabled travellers. The MoBIC travel aid used both GIS and GPS systems in outdoor environments (Abascal & Civit, 2001). The outdoor positioning system was based on signals from satellites, which provided orientation and navigation assistance during the walk. The signals went to the computer to convert this data, which gave the user position on an electronic map of the locality. The output from the system was in the form of spoken messages. In addition, blind users could study and plan their routes in advance by using the route planning system, designed to allow a blind person to access the information from many sources such as bus and train timetables as well as the electronic locality maps by MoBIC (Strothotte et al., 1996). The MoBIC research outcomes have been used effectively in the Brunel research project.

2.2.4. DRISHTI

The Drishti, which means ‘vision’ in Sanskrit, is an integrated indoor/outdoor wireless navigation system for visually impaired people, developed by researchers at the University of Florida. The system guides the blind user based on static and dynamic data, and transmits route information to visually impaired people that helps them to navigate through dynamic indoor and outdoor environments (Ran et al., 2004; Helal et al., 2001). Outdoors, Drishti uses DGPS, which is a location-based system, to keep the user as close as possible to the central line of sidewalks, providing the user with an optimal direction by using a dynamic routing and a rerouting ability, such as ongoing groundwork, resulting in the selection of routes involving fewer hazards and less distance.

Rerouting is supported if unexpected events occur, and travellers can add notes about certain conditions or problems encountered as a reminder if the route is revisited (e.g. a pothole in the pavement) (Ran et al., 2004). On the other hand, the user could switch the system from an outdoor to an indoor environment with a simple vocal command. An ultrasound location system was also developed and used to provide precise indoor location measurements. The user can ask information about the room's layout and the positioning of any furniture. In the study, the user's location was compared to the spatial database of the 'smart house', and the relationship between the user and the indoor facilities was computed.

Drishti gives travel prompts about possible obstacles to the users to help them avoid such obstacles. In addition, the system provided the user with systematic walking guidance. The indoor service of Drishti was bundled under the Open Service Gateway Initiative framework to make it compatible with other services offered by smart houses, such as opening the door for a visitor and checking the weather using a phone(Ran et al., 2004; Moore, 2002).

Drishti integrates some hardware and software components involving a wearable computer, GPS receiver, GIS, an electronic compass, components for various wireless connections, and a vocal communication interface designed to guide users and help them travel independently and safely, which transmits detailed explanatory cues using text-speech software and executes verbal commands of the user using voice recognition. Moreover, a spatial database manages GIS datasets; a route store defines, traverses and analyses complex geographic networks; and a map server serves the GIS datasets over the Internet (Ran et al., 2005; Moore, 2002; Helal et al., 2001). However, the database in this project differs from those of other projects, which are located in remote servers that allow updates only on the server. The mobile unit uses the wireless network to acquire the updates from the server. This project is costly, due to the required staff needed to continually update and survey, especially if the system is implemented to cover a wider area, which needs to cover all the dynamic and stationary obstacles.

2.2.5. NOPPA

The NOPPA project existed from 2002 to 2004, and was designed by VTT in Finland (Turunen et al., 2006). The main goal of this project was to build a navigational aid for the visually impaired to produce an unbroken trip chain using commercial passenger information and personal navigation services without difficulty and expensive changes in the infrastructure (Turunen et al., 2006). NOPPA was developed to provide pedestrian guidance and public transport passenger information for users of public transport using task-oriented client server and user-centred approach to provide the information required by particular user groups, especially the visually impaired; however, sighted people can also benefit from it (Turunen et al., 2006; Hunaiti, 2005).

The system NOPPA included a speech user interface, GPS functions and several information services. NOPPA is based on personal navigation components and services. Modularity has enabled constant development of the system and has helped keep the costs low. Moreover, NOPPA uses public service databases over the Internet, which ensures the information is recent. This system shared the same shortcomings with the system mentioned earlier (Hunaiti, 2005).

2.2.6. NAVITION

Few scientific publications have been found recently in this narrow field. However, a group of researchers from the Technical University of Lodz in Poland designed a system for remote guidance for the blind, under a project called ‘Navition’, which has the same aim and field that the BNSB researched. The main idea of Navition project is to assist the blind user, using a mobile application, through the journey by short-spoken instructions transmitted to the sighted guide, which is an operator’s application. The sighted guide gives instructions depending on a video stream, which is received by a camera carried by the visually impaired person. The project included GPS, GIS and the digital map, which can help the sighted guide using the operator’s application to know the position of the blind user. Thus, the communication link between the two applications was established over the GSM network, using High- Speed Downlink Packet Access data transfer (HSDPA), used to transmit the voice, video and other data (Bujacz et al., 2008a; Bujacz et al., 2008b; Baranski et al., 2009). The aims of this project were:

1. To measure the potential usefulness of the system and discover possible problems with user-operator communication or device design indoor area (Bujacz et al., 2008b).

2. Testing the overall tele-assistance concept in an outdoor area (Bujacz et al., 2008a) by examining the influence of communication link efficiency and reliability on mobility and safety, GPS accuracy and the improvement of operator-user interaction.

3. Presenting the performance of the system in an urban area, which was conducted by including a reliable communication link, GPS accuracy and camera resolution. This was implemented through trials of guiding

the user in a university campus and helping them cross the street and locate a tram (Baranski et al., 2009).

Additionally, the results of this project show that the system is useful and has great potential, although further improvements are necessary (P. Baranski et al., 2009). Moreover, performance increases when travelling with a remote guide (Bujacz et al., 2008a), increasing travel speeds, with decreased occurrences of missteps and collisions (Bujacz et al., 2008b).

2.2.7. VISIO.ASSISTANT (IVES)

Interactivity Video and Systems (Ives) is a Video Live on Demand (VLoD) provider developed by a French company in July 2006. The concept of VLoD is based on live video conversations between two video terminals. The tele-assistant is one of the main services assisting the remote guiding of the blind by sighted guides via mobile videophone call. Over wireless networks (e.g. WiFi), the transmission link is established to connect the two terminals, which help to transmit video streaming. This video streaming has been taken by the camera that the blind person is hold to scan the path in front of blind person (Ives, 2008).

2.2.8. MICROLOOK: E-GUIDE FOR THE BLIND

MicroLook is another tele-assistance system for the remote guidance of the blind, developed by a Polish company Design-Innovation-Integration (‘Microlook’). Microlook aims to increase the freedom of VIUs in everyday life, facilitating their social and professional mobility. The project integrates a mobile phone connected to a micro-camera, earphones and a microphone installed in a special pair of glasses. The video streaming from the camera and sound from the microphone are sent via the phone to a guide's workstation. There is currently no published working relating to this project in any scientific literature (Microlook, 2008).

Over the period in designing and establishing the systems, each project from those systems comes to cover and solve the shortcoming of the previous projects such as the database problem in project of MoBIC. This problem is considered as a major limitation the reason that the large amount of the data and the update of this data, which the system need to save it in the VIUs terminal to support the GIS and obstacle information. This problem was solved by including the database in the remote server in the guide terminal, which is supported the data to the VIUs by wireless network. This is one example was explained the improvement which happened in application, therefore, many other examples are mentioned in some studies that are explained the improvements in these systems, which is explaind in further details in Chapter 3, such as the GPS problem (Nabhan, 2009), network problem (Alhajri et al., 2008a; Alhajri et al., 2008b) and database (Almasri, 2009). However, there are still further limitations and shortcomings that need to be solve, which are common in all the previous systems such as the cost, size, weight and the limitations that related to the satisfy the VIUs such as equipment location, which affect the cosmetically and aesthetically acceptable of the VIUs or interfere with the user’s natural sensation. Furthermore, another very important limitation that the most of the systems were not mentioned in any study related to the Human Computer Interaction (HCI), which is the main part related to the guide terminal, except limited study referred in BRGS, which is explained later in details. The HCI is an important part, which connect the remote guide with the computer in the new systems that use the remote guidance. Below is an explanation about the HIC retreater review and definitions that related to this project and it is useful to understand the importance to this limitation.

2.3. HUMAN COMPUTER INTERACTION:

The relation between the human factor and computer is divided into two main topics that are related to functionality of the software and software interface design. The main functionality of the software is to help users to use it to support or replace their activities (Sears & Jacko, 2008; Zaphiris & Ang, 2008). Moreover, software interface is to provide the information that the users hear or see by the computer, which enables them to control the input mechanism of this information on computer. On one hand, the functionality of the software should be designed to maximise the task performance and minimise the ergonomic problem (Gulliksen et al., 2009; Zaphiris & Ang, 2008); on the other, the software interface design is based on the cognitive and perceptual abilities of humans, and the application of the display and the control principle (Gulliksen et al., 2009).

A good software interface can have a sizable impact on learning time, performance speed, error rates and user satisfaction (Wickens et al., 2004). Using the hardware and software creates an interaction between the computer and the user, which is called a Human-Computer Interaction (HCI). Historically, HCI emerged from the two disciplines of psychology and computer science.

HCI is a multidisciplinary subject that addresses the issue of how users use computers (Cox et al., 2008). However, it encompasses other fields, such as education, business, design and development, information technology and computing, library services and entertainment (Giacoppo, 2001). Philosophy, social sciences and cognitive ergonomics are all disciplines related to the HCI methodology (Cox et al., 2008).

The Association for Computing Machinery defines HCI as '*a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them*' (Gawande, 2009). The purpose of the HCI is laid down over three levels; development, task and interface. HCI is used in the development level to develop interaction techniques as well as to suggest where and in what situation these techniques might be put to best use, depending on the interaction between Hardware (HW) and Software (SW) (Booth, 1989). The task level creates methods for determining users' needs, to ensure that systems provide users with the right functions and information required (Sears & Jacko, 2008; Wickens & McCarley, 2008; Wickens, 2008). The interface level creates a link between the users and the learning content, which allows the former to access, use and manage the latter through an interface (Seok, 2008; Ciavarelli, 2003; Harris, 1999).

The most of the new applications are supported by using multitask; which is became an important feature of the modern computer (Iqbal & Horvitz, 2007). Multitasking runs or monitors different applications at the same time, such as communication (e.g. video text chat) or software applications (e.g. Internet

Explorer, MS Word document). Furthermore, it runs or monitors two or more different tasks in the same application, such as video games or driving simulations. Multitask applications might utilise the same sense (e.g. visual-visual), or use different senses together (e.g. visual-auditory) (Wickens, 2002). One of the most important applications in multitask is multiple display, whereby users utilize their sense of vision to monitor different displays.

Visual display is considered a link between the users and the computer, which is used to present the information in an easily comprehensible visual form. Moreover, the information must be displayed according to principles in a manner that supports perception, situation awareness and understanding (Morrison et al., 2010; Ware, 2008; Tufte & Howard, 1983). Before the visual display is designed, system requirements should be defined clearly, such as navigating, controlling, decision making, learning and entertaining, with respect to the end user’s desire (Morrison et al., 2010; Ware, 2008).

These requirements enable the user to process whatever information the system generates and displays (Freeman & Julious, 2005; Shneiderman, 1997). According to the visual display definition, multiple displays use more than one visual display, which requires attention from the user. This attention is known as visual attention, considering the ability and the performance of the user while displaying the information within multiple displays. However, visual attention could be focused on one display that has the most important information without ignoring the other display. Researchers have used the Response Time (RT) or accuracy as a measurement level for the difficulty of the visual search task, as well as the performance of the user (Doucette, 2010).

Attention is a subject that all users naturally understand. Users are constantly faced by a complex visual stimulation from the environment, which makes them select only the relevant information from the environment and ignore superfluous information, in order to minimise their mental workload and maximise their cognitive control over what they select from the visual environment (Wickens & Alexander, 2009; Wickens, 2008). Attention can be defined as the cognitive process whereby a user concentrates on one aspect or feature of the environment to the exclusion of the others (Doucette, 2010; Wickens et al., 2003; Egeth & Yantis, 1997). Furthermore, it could be defined as ‘the mental ability to select stimuli, responses, memories, or thoughts that are behaviourally relevant among the many others that are behaviourally irrelevant’ (Corbetta et al., 1990). The term ‘attention’ is also often used to refer to other psychological phenomena (e.g. the ability to perform two or more tasks at the same time, or the ability to remain alert for long period of time). Researchers often divide attention into five types: focused, selective, switched, sustained, and divided. These are based on two main input channels: visual and auditory (Roda & Thomas, 2006; Theeuwes & Godijn, 2001; Egeth & Yantis, 1997).

Many studies on multitasks have been carried out under the term of HCI, which aims to test users’ performance and efficiency. Some studies under the multitask topic have been done on multiple displays, which have used different senses (i.e. visual and auditory) to test users’ attention and response. Some studies have used different senses; Dixon et al. aimed to examine pilots' performance by using simulations of unmanned aerial vehicles (UAVs). In this simulation, the number of concurrent tasks were increased while the pilots control one or/and two UAVs. The pilots were responsible to navigate the UAV to complete the mission, search for targets and monitor the system in baseline condition, using the manual flight control and visual display; in auditory offload condition, using auto-alert and relevant information to the auditory channel; and in automated condition, which supported the auto-pilot control of the UAV. The main results were showed that the two offloads were useful in decreasing the task interface and overall workload, as well as the possibility of one pilot concurrently controlling two UAVs.

Horrey and Wickens tested the effect of display clutter from overly and display separation on driving and In-Vehicle Technology (IVT) task performance. In this study the drivers used a fixed-base simulator to drive different routes and respond to unexpected road hazards while engaging in a phone number task presented in a different interface (visual displays were located on a head up or head down); digits were presented auditorily. The results showed that there were no differences in performance for the overly display; nevertheless, there were a difference in responding the road hazard related to the head down display and auditory display.

Whereas other studies focused on the use of visual sense with multiple displays to monitor the visual attention for the users. The guide terminal in BRGS is one of these applications that used the visual sense to test the sighted guides' visual attention to monitor two-screen displays (video screen display and digital map display). The guide terminal is one of the examples that came under the human-computer interaction applications. However, this kind of HCI applications is called a multitasking application for the reason that the sighted guide needs to use and operate two screen displays, which have a different task, to gain the information to assist the VIUs to avoid obstacles by using the video image display on one screen as well as to provide the VIUs direction by use of the digital map on the second screen to reach the destination. Furthermore, guide terminal is used different displays at the same time, which defined as a multiple displays application, which has mentioned before that the multiple displays require dividing the attention between different tasks at the same time (i.e. this meant the ability of the sighted guide to operating two screens while displaying the information at the same time). This ability could evaluate the sighted guide in dividing the attention between the two screen displays.

Again, the performance of user attentions in a multiple displays application might be affected by adding or changing some features of the display screen "i.e. the application interface" such as: using different frame rate while streaming the video image, located the display screen in different place or different angle, using alert or increase the tasks during monitor different display screens, using different display screen resolutions or using different display screen with different purpose. Before the multiple displays studies are taken place; two studies need to be explained which have a related link to the main study of this work.

Garaj et al. conducted a study to evaluate the effect of the video frame rate on the recognition performance of the sighted guide in recognising the stationary environment hazard. However, in this study one display was used, which tested the sighted guide visual attention in one display. The authors used different frame rates (25 and 2 fps) in a laboratory simulation to test 20 participants recognition performance in aiding the visually impaired users. The result for this study shows there is no significant difference in using different frame rate on the recognition performance of the sighted guide (Garaj et al., 2010). Similar study was conducted by Hunaiti et al. to determine the most acceptable quality of the video image, which used in the remote guidance of visually impaired pedestrians. In this study also one display was used to measure the sighted guide performance and satisfactory by using three factors: different screen resolution (QCIF (176 x 144 pixels) and CIF (352 x 288 pixels)), different video image frame rate (10, 7.5, 5 and 2.7 fps) and different video image encoding (30 and 48 Kbit/s). The results showed that there is no significant difference between using those factors and the participants were more comfortable to use the video which was transmitted at 48 Kbit/s and 7.5 fps and using the CIF resolution for stream the video image (Hunaiti et al., 2009).

Again, the following studies explain the effect of adding or changing some display screen features on the user attention performance; Weisz et al. conducted a study that measured users' attention to examining the viability of an active social engaging experience by observation of both a text chat screen and a video film. The findings of this study showed that chatting and watching a video film at the same time has a social benefit, although it has also been found that there is distraction, for which intermissions have been recommend (Weisz et al., 2007).

Furthermore, Iqbal used multitask to test the concentration of users on the suspension and resumption of tasks by logging users' interactions with software applications and their associated windows, as well as incoming instant messaging and email alerts. The main outcome from this study was that the association between faster resumption and greater visibility of windows of suspended applications of tasks, suggesting that visual cues may serve as reminders to return to suspended applications (Iqbal & Horvitz, 2007).

2.4. SUMMARY

In this chapter, different projects have been mentioned that shared the same aim, which is helping the VIUs to be mobile by providing some assistance by the automated system, sensors or remote sighted guide. Different limitations have been pointed out from these systems, however, some of these limitations have already been solved and the other needs to be resolve; In addition, one of the main limitations, which has been mentioned previously was the part that is related to the HCI and the link between the user and the computer. Research was conducted to explore the elements of BRGS in general and the guide terminal in specific. This will help the researchers to understand and have a clear vision of the BRGS elements and their evaluation methods, which help them to cover and solve the limitations in one side and to allow them to improve this project before the final deployment.

CHAPTER 3

BRGS PERFORMANCE FACTORS ANALYSIS

3.1. INTRODUCTION

Most of the research conducted on BRGS was focused on the technical implementation and improvement aspects of the project (Nabhan, 2009; Garaj, 2006). However, limited research was conducted on identifying the performance factors in each element, as well as the method of their assessment. These factors will have a direct impact on the system performance prior to the final deployment of this system; further research needs to be conducted to evaluate the different factors of BRGS that could have impact on the overall performance of the system.

3.1.1. *BRUNEL REMOTE GUIDANCE SYSTEM:*

Several research projects have been conducted aiming to help improve VIUs' lives by increasing safety, independence and comfort (thus facilitating mobility). Brunel Remote Guidance System (BRGS) is a project that assists VIUs based on providing guidance instructions via a remote sighted guide, enabling VIUs to avoid obstacles and reach their destinations. BRGS is based on integrating state of the art technology consisting of satellite navigation (GPS), wireless broadband, digital mapping (GIS), databases, and real-time video streaming. BRGS is currently being developed by a navigation research team within the Centre for Electronic Systems Research (CESR) at Brunel University.

The prototype of this system (see Figure 3.1) has been established and tested with end users, showing a very promising outcome towards improving VIUs' quality of life (Garaj et al., 2003). Furthermore, it has been proposed to employ the concept of remote tracking and navigation using GPS, GIS and video/voice transmission over the 3G mobile networks, in aid of VIUs. Wholly consistent with the remote navigation concept, the equipment used in the BRGS is designed to enable a VIU utilising the system to be remotely assisted by a sighted human system operator (Hunaiti et al., 2006b). As in the case of EOAs, the assistance obtainable through the BRGS is intended as additional mobility support, supplementing the use of long canes or guide dogs.

BRGS consists of mobile and stationary terminals. The mobile (user) terminal is used by a VIU, who is assisted by a remote sighted guide during the journey, whereas the stationary (guide) terminal is utilised by a Sighted Guide (SG), who provides the remote guidance instructions. In this study, 3G wireless communication link was used to establish the connection between the VIUs and SG (Hunaiti et al., 2006b; Garaj et al., 2003). Voice communication is transmitted via a wireless link between the VIUs (via mobile phone in the mobile terminal by using a microphone and a single earpiece) and the SG (via a landline phone in the guide terminal by using headphone and microphone). This bi-link is important to allow a real time interaction between the SG and the VIUs. Additionally, wireless link is used to transmit the GPS location and video image from the user terminal to the guide terminal displayed on two- screens, as shown in Figure 3.1.

GPS data is displayed in the digital map screen by using the GIS database. The map enables the SG to track the VIUs during their journey and navigate them to the desired destination. The video image is displayed in video image screen and it allows the SG to assist the VIUs by describing the environment ahead. The video image is streamed from the user terminal camera. These data provide valuable information about the mobility of the VIUs (i.e. navigation and orientation) (Hunaiti et al., 2009).

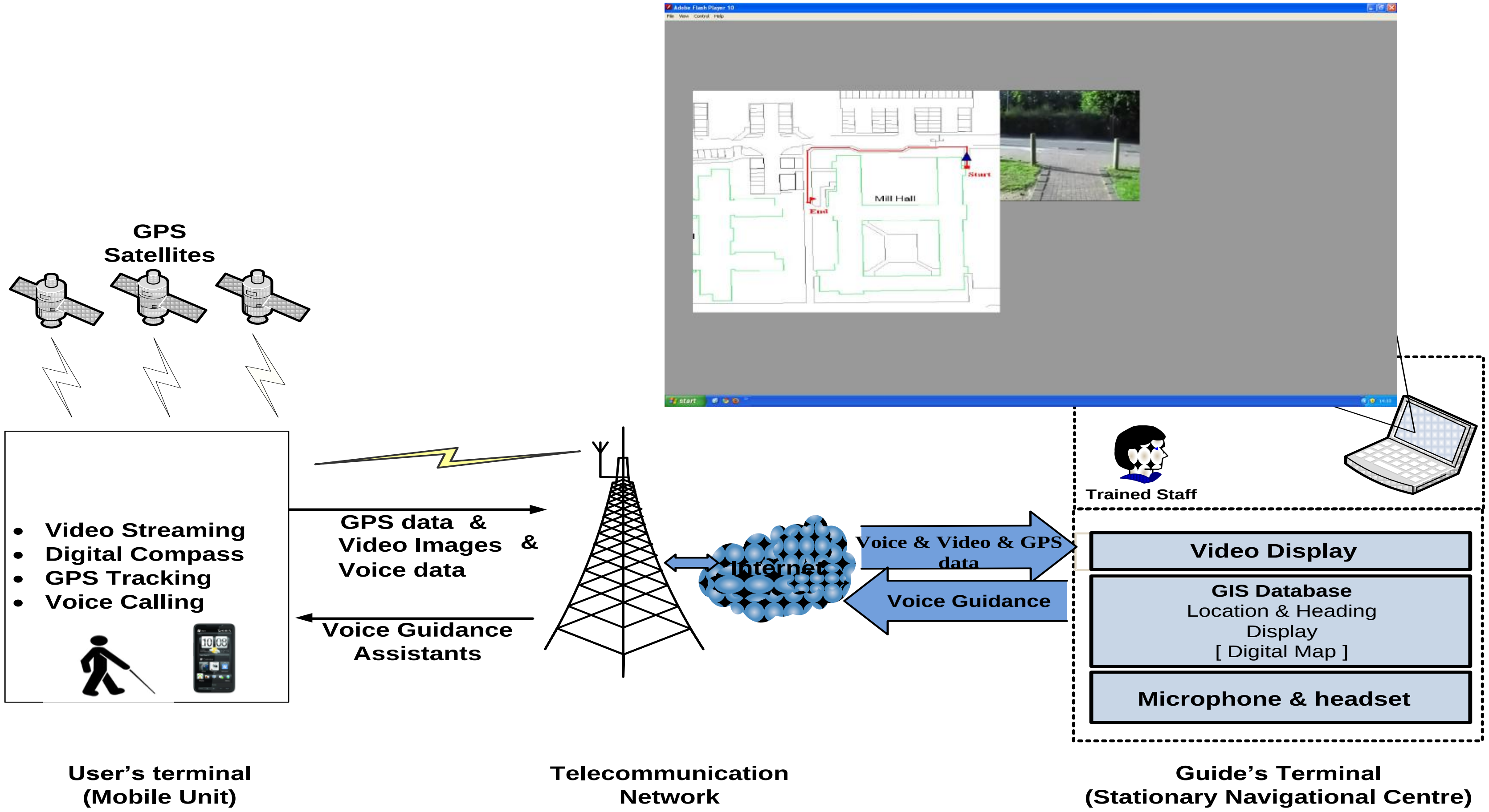


Figure 3. 1 Brunel remote guidance system prototype

3.2. STUDY DESIGN

In this study a systematic review methodology (Kitchenham et al., 2009; Brereton et al., 2007) has been used, which focuses on and provides an extensive summary of literature relevant to research questions (i.e. identifies, appraises, selects and synthesizes all high quality research evidence relevant to the enquiry). The flowchart in Figure 3.2 shows the steps followed, to give an understanding of the main procedure of this study.

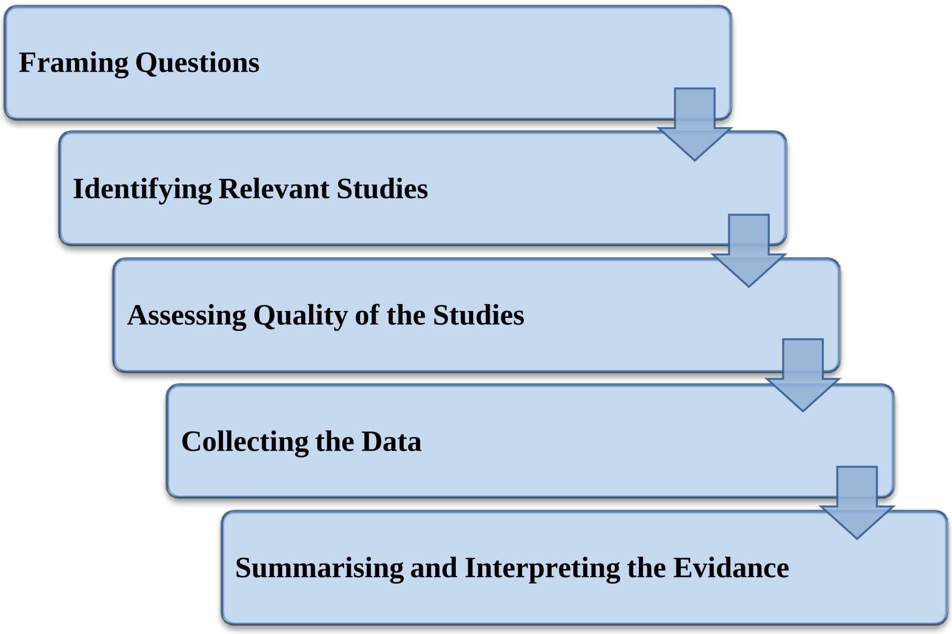


Figure 3. 2 Systematic review flowchart procedures

3.3. RESEARCH QUESTIONS

The first task was to frame the research questions, which can be summarised as follows:

1. What are the main sub-systems that might impact the whole BRGS?

2. What are the main factors within each sub-system that influence the BRGS performance?
3. Is there any method for evaluating each factor within each sub-system in BRGS?
4. Is the performance method can be conducted?
    - **Yes** for those methods can be conducted (based on the committee's judgment).
    - **No** for those methods cannot be conduct (based on the committee's judgment).
    - **Not available** for currently non-existent methods.

Following that, from all the literature related to this system, only 12 studies were identified as directly related to the BRGS performance, thus they were selected.

Content analysis method was used to assess the quality of literature and collecting data (Neuendorf, 2002). This method requires pre-identifying certain criteria (i.e. objectives) through an in-depth investigation of the available resource (i.e. contents). This can be related to the research subject. The objective of this part of the study is to answer the aforementioned questions. The mechanism of the contents analysis within this study is illustrated in Figure 3.3, and the answers to questions are presented in the following sections.

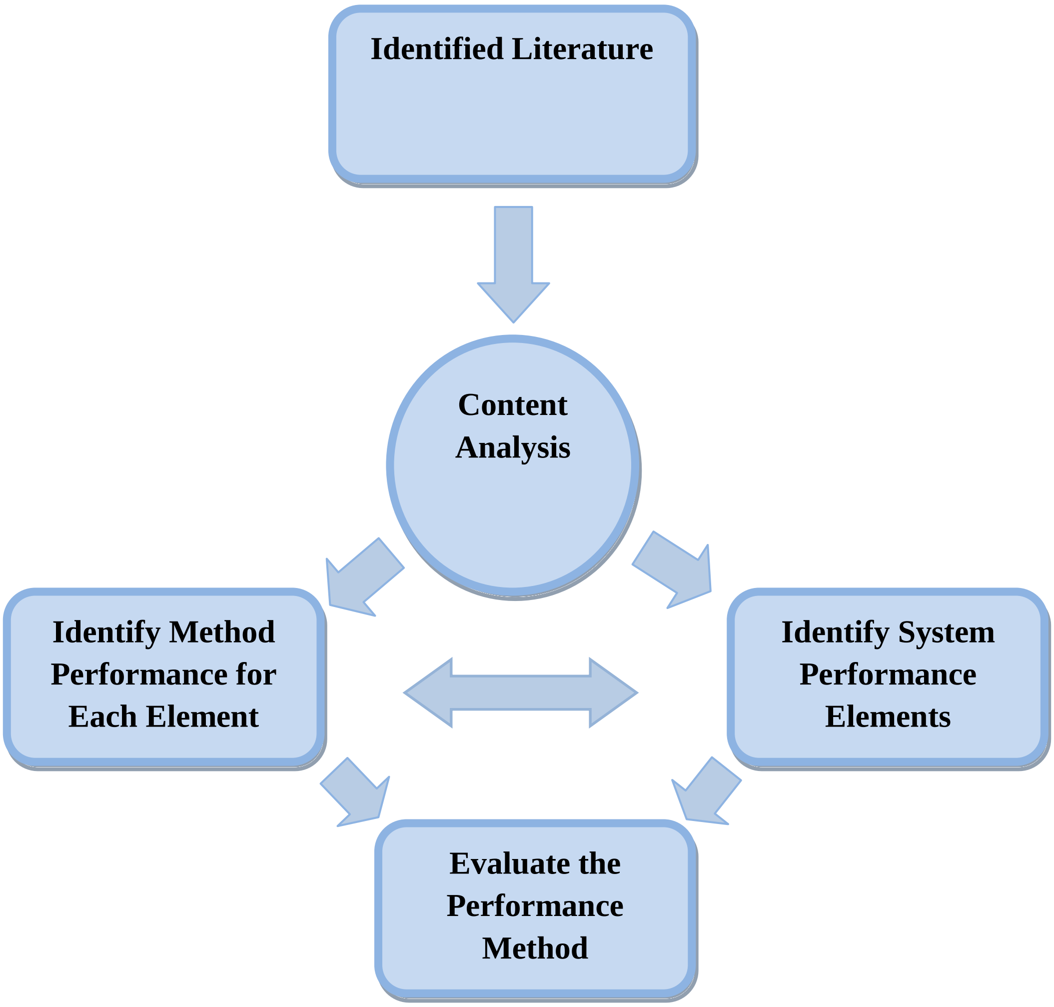


Figure 3. 3 Content analysis flowchart

3.4. PERFORMANCE ELEMENTS AND FACTORS

The architecture of BRGS can be divided into four elements, as illustrated in Figure 3.4. Each element has many factors that affect the performance of the overall BRGS system. Element can be divided into two main categories; technology based elements (i.e. communication and location technologies) and technology and human based elements (i.e. user and guide terminals). These two categories can be graphically presented, as shown in Figure 3.4.

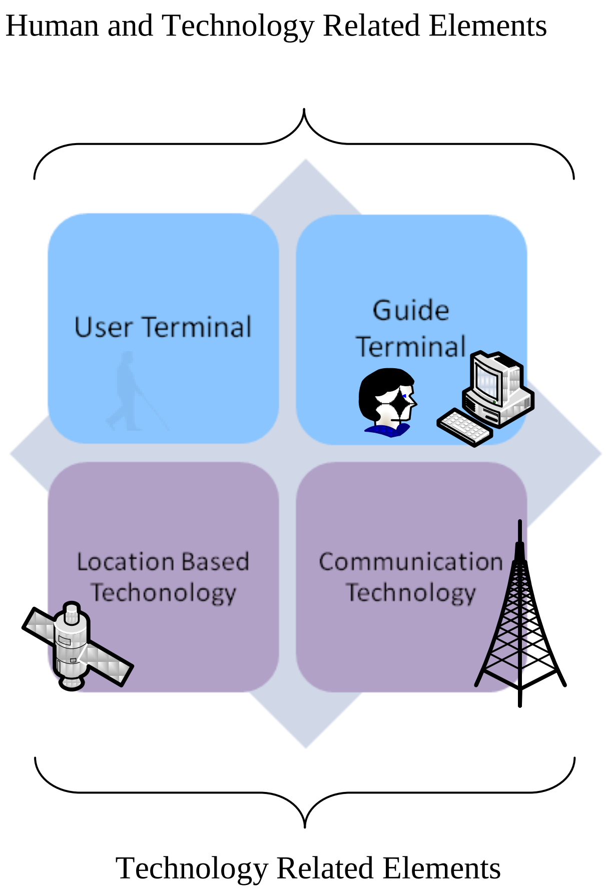


Figure 3. 4 The elements of Brunel remote guidance system

3.4.1. HUMAN AND TECHNOLOGY RELATED ELEMENTS

This part of the BRGS is based on HCI, which is included human (i.e. sighted guide and visually impaired users) and computer (PC in guide terminal and mobile in user terminal). In this part there are two elements: guide terminal and user terminal. The following sections describe each element with further information related to the performance factors and the equipment's, which have been used in each element. Figure 3.5 illustrates the human and technology elements flowchart.

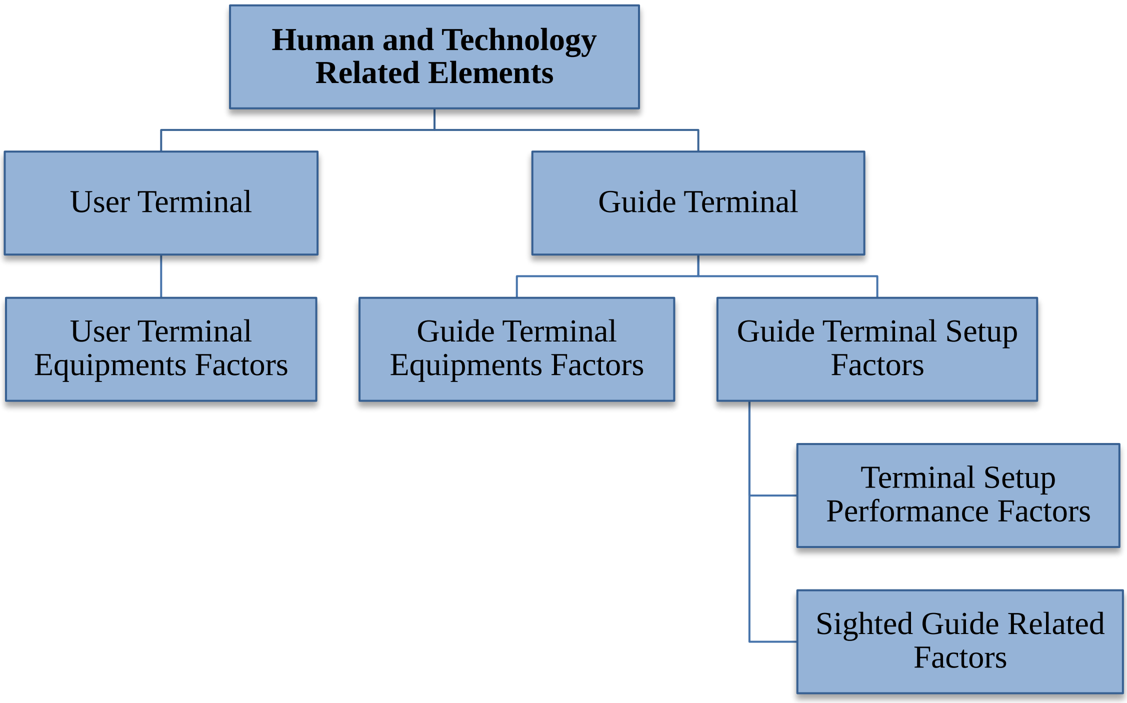


Figure 3. 5 Human and technology related sub-systems

i. User Terminal

User terminal is the mobility aid unit, which was designed to be easily carried by the user. The main function of the mobility aid unit is to transfer real time data from the user terminal to the guide terminal. Seven factors were identified in this mobility aid unit, which might have a direct or indirect impact on the performance at the element (i.e. user's terminal) level or the overall system:

a) **Speakers:** provide the means for the guidance instructions provided from the guide personnel to the user. The speaker should not block the hearing sensation, and should allow the user to hear the surrounding environment, which will help to increase the user's confidence (Dakopoulos &

Bourbakis, 2009; Lutz, 2006; Ross & Blasch, 2000). Proposed examples for the location of speakers are:

- On the shoulders. This will allow the user to hear the guidance instructions and the surrounding environment without blocking the hearing sensation. However, there is the potential for the surrounding environment noise to affect the hearing instruction, which will decrease the guidance performance (Gustafson et al., 2007). Furthermore, this noise might help the user to recognize the surrounding environment (Gustafson et al., 2007).

- Speakers can also be located in a single earpiece. It will increase the concentration of the user as well as allow them to hear the surrounding environment. However, the earpiece will inhibit hearing, which will interfere with the user requirements (Lutz, 2006; Walker & Lindsay, 2006).

b) **Camera (general setup and degree):** transfers the real time video data of the environment ahead of the user to the guide terminal. Moreover, this video data helps the sighted guide person to detect obstacles and assist the visually impaired pedestrian by giving the right instructions to reach at the destination. The general setup of camera, such as zooming and focusing, needs more attention (Loomis et al., 2002). Furthermore, focusing on the camera degrees and field of view are necessary to achieve the optimal required view, which enables detection of the obstacles from the lowest level of the body to the head level (Garaj et al., 2010; Dakopoulos & Bourbakis, 2009; Hunaiti et al., 2006a).

c) **Compass:** helps the guide person to know the user orientation, and specifically helps the guide to know which direction the blind person is facing (Ross & Blasch, 2000). Any certain major need to be considered that depends on the types of compass used in the system. For instance, some magnetometer based compass is required within strong local magnetic fields (Dakopoulos & Bourbakis, 2009; Jones, 2006; Garaj, 2006; Ross & Blasch, 2000).

d) **GPS and GPS antenna and its location:** GPS receiver uses the satellite signal via GPS antenna to locate the position of the user (Dakopoulos & Bourbakis, 2009; Ran et al., 2005; Latifovic & Olthof, 2004; Seynat et al., 2004; Ross & Blasch, 2000). The GPS accuracy is very important to increase the guidance performance services. GPS antenna should be located conveniently for the user, as well as with a direct view of the sky. This is to ensure direct line of sight to all visible satellites overhead, and to minimise signal noise or loss. In addition, the GPS should be with quick-time start up to fix the user's position quickly (Nabhan, 2009; Golledge & Marston, 2005; Latifovic & Olthof, 2004; Seynat et al., 2004).

e) **Microphone:** transfers the voice from the user to the guide with minimum noise effect. A suitable location for the microphone is near the voice source (i.e. mouth) (Cardin et al., 2007).

f) **Function keys:** assists the user to operate the system during normal and emergency mode. The function key should be in an accessible place, with the minimum number of keys (Hunaiti, 2005; Garaj, 2006; Szeto, 2004).

g) **Battery:** Power supply to keep the user equipments running. The battery has to be rechargeable with high energy density to be able to provide power to all equipment for the period while the user is on the move. Simultaneously, it should not be large or heavy enough to cause a burden on the user (Starner, 2010; Hunaiti, 2005; Hahn & Reichl, 2002; Ross & Blasch, 2000).

The mobile aid unit can optimally enhance the overall performance of the system by considering the following further requirements (Cesetti et al., 2010; Peris et al. 2010; Dakopoulos & Bourbakis, 2009; Hunaiti et al., 2006b; Szeto, 2004):

- Cosmetically and aesthetically acceptable.
- Does not interfere with the user's natural sensation.
- Lightweight and small size.
- The information provided by this mobility aid unit should be intelligible and clear.
- Reliable and it should be water-proof, which can be used in bad weather conditions.
- Batteries should be rechargeable and replaceable.
- Wearable and hand-free to allow the user to use other aids though the travelling.

- Free maintenance and runs on standard.
- Easy to store when not in use.
- User friendly.

ii. Guide Terminal

The purpose of this research project is to design a “guide terminal interface” that provides the necessary information needed to mobilize visually impaired pedestrians without providing any superfluous information. This has the prospect to increase the cognitive load on the sighted guide to enhance the performance of BRGS. The previous flowchart (Figure 4) showed the main factors for the guide terminal.

a) Guide terminal equipment’s element:

Guide terminal consists of essential equipment, each component of which performs important functions:

I. **GIS database:** presents the user location on the digital map during the journey. This tracking process will enable the sighted guide to correctly position and track the visually impaired pedestrians to reach their desired destination (Garaj et al., 2003).

II. **Personal computer based workstation:** should include a suitable user interface, with a video and map display. Information provided by the video and map will describe the environment ahead of the visually impaired pedestrians. The digital map display will be used to view the position for the visually impaired pedestrians and to help the sighted guide to know the right path reaching the destination (Hunaiti et al., 2006b).

III. **Headset and microphone:** the guide terminal should be equipped with a voice communication unit to enable the sighted guide to interact with the visually impaired pedestrians. The voice communication unit should be based on a hands-free microphone and earphones set (Hunaiti et al., 2006a).

b) Guide terminal setup element

The setup factor for the guide terminal can be divided into two (see Figure 4). The first category of these factors is related with the guide interface setup, installed in the guide terminal. The second category is related with the sighted guide person, who needs to utilise the guide terminal. Further explanation is given below:

I. Guide Interface Performance Factors:

The performance factors for terminal setup might be affected by the following aspects:

1. **GUI layout**: the location of each element within the sighted guide interface (display) system.
2. **Video image and Map size**: by using the standard size resolution of the 3G telecommunication that will help to find the optimum size for the video image and the digital map display (Garaj et al., 2010; Hunaiti et al., 2006a).

3. **Video image quality**: The quality of the video image should be acceptable for the application in remote guidance system. Moreover, the video image should be suitable to be transmitted via the wireless network without loose of data (Garaj et al., 2010; Hunaiti et al., 2006a; Thompson et al., 2004).
4. **Other essential data**: Sufficient data to detect obstacles and path information should be recognized as early as possible within a contained distance. Prior essential information should be provided to the sighted guide in advance such as bad weather condition, road closures or natural disasters (Gaunet & Briffault, 2005).

II. Sighted Guide Related Factors (sighted guide responds):

Factors that might have impacts on the sighted guide’s performance, which will consequently affect the overall performance, are addressed bellow:

1. **Macro-Navigational Error (MaNE):** is the ability of the guide’s person to recognise any error on the route that is taken by the user. Guide’s person should report and lead the user back to the original right route.
2. **Micro-Navigational Obstacle Recognition (MiNO):** guide person should be able to recognise obstacles during the user journey. Moreover, guide person should be aware of two kinds of obstacles, identified as primary and secondary. The type of the obstacles should be reported by the guide person to the user, to navigate safely around them (Green, 1966).

3. **Micro-Navigational Obstacle Distance Recognition (MiND):** in order to avoid obstacles, there is a need to have a safe distance that the sighted guide needs to report the obstacle in advance. This is to allow the user to have a sufficient response time and distance to navigate around the obstacles adequate (Jones, 2006; Dowling et al., 2005; Ross & Blasch, 2000; Green, 1966).

3.4.2. Technology Related Factors:

Communication and location technologies are under constant improvement. Consequently, these have improved the BRGS efficiency significantly. These two technologies are considered to be elements, as illustrated in Figure 3.6.

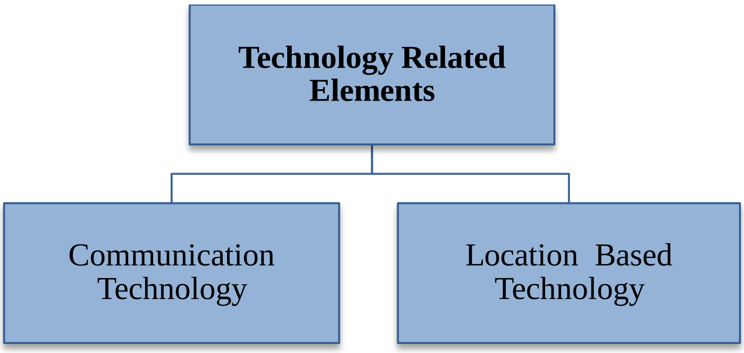


Figure 3. 6 Technology elements

i. Communication Technology:

The BRGS was established to use existing public wireless broadband infrastructure to handle the data between the visually impaired pedestrians and the guidance centre as an easy to use and low cost deployment of the system. However, due to the fact that wireless signals are subject to degradation in quality of service because of the nature of communication medium of free space, which is directly affected by bandwidth, delay, packet loss and link outage (Hunaiti et al., 2009; Sedoyeka et al., 2008; Hunaiti et al., 2004). Special consideration needs to be given to guarantee sufficient quality of service. Factors which can affect communication link as listed below:

a) **High bandwidth:** allows transmitting data, such as video streaming and location information, between the user terminal and the guide terminal in high speed (Sedoyeka et al., 2007; Lai & Baker, 2002)**.**

b) **Low delay:** the safety of the visually impaired pedestrian is affected by any delay in delivering the navigation data. Furthermore, this delay will increase the risk, which will increase the mismatch between the real position of the visually impaired pedestrian and the position shown on the guide’s display (Sedoyeka et al., 2007).

c) **Low packet loss:** packet loss will affect the user guidance, either by not providing the essential information or the lag of information. Missing data might lead to misguiding either the visually impaired pedestrians, the sighted guide or both (Hunaiti et al., 2009).

d) **Low outage:** the disconnection time between the interrupted and the re-established connection, which will impact the reliability of the BRGS (Sedoyeka et al., 2008; Hunaiti et al., 2004).

All the previous quality of service factors are influenced by phenomena such as network coverage, operational time (peak time or off-peak time), geographical location (if the user is indoors or outdoors) and number of users. The nature of this particular application requires high quality of service, which can be achieved by certain arrangements and collaboration with the wireless operator. A monitoring mechanism can be incorporated, which can alert a sighted guide when the signal quality descends to an unacceptable threshold to maintain quality of service (Sedoyeka et al., 2008), such as in the event of a user entering into a poor network coverage zone, or experiencing low bandwidth (a situation that would be more problematic with the old generation of wireless broadband). With the advancements of recent mobile networks, such problems have become less problematic (Alhajri et al., 2008a; Alhajri et al., 2008b).

ii. Location Based Technology (Tracking and Positioning Technology)

Location based technology depends on tracking and position technologies, which are considered to be an important part of the BRGS. Such technologies will enhance the performance of the sighted guide to track the user during their journey to navigate them to reach their desired destination (Nabhan, 2009). However, some factors should be taken into account to increase system performance, such as

a) **GPS accuracy**: GPS determines the position accuracy of the visually impaired pedestrian accurately. The accuracy is defined as the statistical difference between the exact position of the visually impaired pedestrians and the measured their position at a given time with respect to an accepted coordinate system (Nabhan, 2009; Latifovic & Olthof, 2004; Ochieng et al., 2002).

b) **Service availability, coverage, and continuity**: service coverage can be defined as a sufficient number of operational satellites accessible in the sky over a surface area at any given time. The availability of such a service can be described by the percentage of time over a specified interval in which a position can be obtained within the service coverage (i.e. information reliability) (Nabhan, 2009; Ochieng et al., 2003). Both the technical capabilities of the transmitter facilities and the physical characteristics of the environment are also under the availability function (Biesen, 2003; Hein, 2000). Continuity is defined as the ability of the mobile unit to complete its function without any interruptions during the operation (Ochieng et al., 2002; Krüger et al., 1994)

c) **Service reliability and integrity**: both the reliability and integrity are related to the correctness and trust that can be placed with regard to the positioning information for the mobile unit in the user terminal (Nabhan, 2009; Hein, 2000). Reliability can also be considered by the mobile unit's consistency of providing the desired service within a specific error tolerance. Integrity consists of the ability to provide timely warnings to visually impaired pedestrians during the journey (Weiss et al., 2007; Ochieng et al., 2003; Ochieng et al., 2002).

All the previous factors have a direct impact on the correct position of the visually impaired pedestrians; this will affect the guidance performance, which consequently affect the overall system location based performance in specific and the BRGS in general.

3.5. Performance Elements Method and Effectiveness:

After the factors have been identified; hence, there is a need for assessment methods to determine whether these factors have a direct or indirect impact on the performance of the system. In the following, typical assessment methods are explained for each factor in the element within the BRGS.

3.5.1. User's Terminal

In the user terminal, the assessment Categories is represented as a check list (see Table 3.1). This list includes the most important system requirement factors. The assessment method helps to choose a suitable device that will be used by the visually impaired pedestrian.

Table 3. 1User terminal assessment categories chick list

	Assessment Categories	Tick	Method Effective
Visually Impaired User Platform	Cosmetically and aesthetically acceptable		Yes
	Not interfere with or effect the operation of natural user senses		
	Light weight		
	Small size		
	Intelligible and clear information providing		
	Not easy to brake		
	Reliable		
	Water-proof		
	Easy replaceable and rechargeable batters		
	Free maintenance and runs on standard		
	Simple single handled controller keyboard		
	Easy to use		
	Short-time is needed to learn		
	Easy to store		
	Wearable		
	hand-free		
	GPS quick time for first fixed		
	Emergency button (panic button)		
	Does not interfere with other primary aids		

3.5.2. Guide Terminal:

So far, one of the experiment tactics is a method that has been used and recommended to evaluate the guide terminal and the sighted guide performance, which requires the necessary Software (SW), Hardware (HW) and human involvement. The system prototype and personal are now available; however, assessment method for the performance factors can be conducted as shown in Table 3.2.

Table 3. 2 Guide terminal performance assessment method

		Assessment Method	Method Effective
Performance Factors	**MaNE**	Can be undertaken by measuring the length of time the visually impaired pedestrians derail from the pre-defined experimental route, which is known by the researcher but not by the visually impaired pedestrians or the sighted guide person. Furthermore, by clocking the time it takes the sighted guide person to recognize that the visually impaired pedestrian is out of the correct route.	**Not available**
	MiNO	This can be measured by counting the number of obstacles correctly recognised by the sighted guide. The probability of detection is compared with the actual number of obstacles within the route. Obstacles are divided into two types: primary and secondary obstacles.	**Not available**
	MiND	Again in an obstacle distance response on the experimental route, this can be done by comparing the sighted guide rate, which has been collected by the calculate number of right distance that the sighted guide has reported during the journey, for the distance between visually impaired pedestrian and obstacle with total right distance rate.	**Not available**

However, some other factors related to setup of the guide terminal are yet to be researched in order to be able to discuss on the method of assessment.

3.5.3. *WIRELESS NETWORK:*

Table 3.3 describe the typical methods for measuring the wireless performance elements:

Table 3. 3 Wireless network performance assessment methods

		Typical Methods of Assessments	Method Effective
Wireless Performance Factors	**Bandwidth**	Typical (method) tools have been used to measure network bandwidth (Sedoyeka et al., 2007; Lai & Baker, 2002), such as using windows performance monitoring or measuring the rate of download/upload between the two terminals (Guide/User Terminal or vice versa)(Hunaiti et al., 2009; Jin & Tierney, 2003).	**Yes**
	Latency	Delay can be measured by using a specific Network Monitoring Tool; this tool provides useful information about the latency status in the network. However, a much easier method is to use 'ping command' under the ICMP (Alhajri et al., 2008a; Sedoyeka et al., 2007); this command can be used under DOS or UNIX operating systems. It will enable the measurements of end-to-end or 'Round-Trip-Time' (RTT), which indicates the amount of latency between the Guide Terminal and User Terminal (Hunaiti, 2005).	**Yes**
	Link Outages	Measuring the time between interrupted and re-established connection (i.e. disconnection time) is identified as some typical mode which allows the measurement of the disconnection time. In this project, this type of measurement is focused on the User Terminal end in the Navigation System (Sedoyeka et al., 2007).	**Yes**
	Packet Losses	Packet losses can be measured using the ping command under ICMP (Alhajri et al., 2008b); this is similar to the proposed technique to measure the latency.	**Yes**

3.5.4. *LOCATION AND POSITIONING TECHNOLOGY:*

In general, the evaluation of GPS service requires a certain experimental setup requiring both hardware and software tools. Evaluation can be coordinated in two scenarios: dynamic scenario (i.e. with mobility) and static scenario (i.e. with zero mobility). Typically, the assessment can be coordinated over a period of time and at a given route with known coordinates. Measured data should be logged into a data file for further analysis in accordance to the given application needs. The following Table 3.4 summarises a simplified approach on conduction assessment on GPS performance elements, which is directly linked with pedestrian applications (Nabhan, 2009; Seynat et al., 2004).

Table 3. 4 Location and positioning performance assessment methods

Location and Positioning Performance Factors		Typical Methods of Assessment	Method Effective
	GPS Accuracy	Different methods can be used to measure the GPS accuracy in the BRGS, such as the accuracy of the reference data, classification scheme, spatial autocorrelation, sampling size, sampling scheme or spatial distribution of error (Foody, 2002; Friedl et al., 2000; Stehman, 2000). The most common of these methods have focused on factors influencing the accuracy assessment of maps, which can be estimated by comparing the measured position at a given route with known coordinate of the same route. Furthermore, reference data and independent classification are created an error matrix, which has been used in methods that used to assess the GPS accuracy. Most of these methods are quantitative methods (Latifovic & Olthof, 2004; Hein, 2000; Guard, 1996; Krüger et al., 1994).	**Yes**
	Coverage& Continuity	Can be determined by the number of the satellites sufficient and visible in a geographical area at period of time (Nabhan et al., 2009 ; Latifovic & Olthof, 2004; Biesen, 2003; Randell et al., 2003) .	**Yes**
	Service Integrity and Reliability	Different methods for monitoring the integrity have been proposed in an attempt to satisfy the integrity requirements. Each of these methods is aimed to check the error exceeds a specified threshold in either an individual measurement or the resulting position. In general, this can be measured by the trust that can be placed in the correctness of the information supplied by the total system (Nabhan, 2009; Grewal et al., 2007; Seynat et al., 2004). Furthermore, the different approaches to the monitoring of integrity of stand-alone and augmented satellite-based navigation systems are external monitoring and Receiver Autonomous Integrity Monitoring (RAIM) ground-based integrity monitoring using an independent network of integrity monitoring stations and a dedicated Ground Integrity Channel (GIC). Satellite Autonomous Integrity Monitoring (SAIM) is based on the monitoring of the performance of the frequency generation mechanism on board the satellite (Weiss et al., 2007; Ochieng et al., 2003; Ochieng et al., 2002).	**Yes**

3.6. CONCLUSION

This research was conducted to analyse different factors that could have impacts on the overall performance of the system. It has been found that there has been limited research undertaken to find the best setup of the guide terminal design, which might have a direct impact on the performance (section 3.4.1.2). The guide's terminal is considered as a major element in the system as it is the core of the guidance service. Mostly, experimental work should be done on the guide's performance, which requires both operational system and human involvement. Moreover, it is important to establish an efficient method to evaluate the performance of the guide terminal within the context of providing sufficient important information for the guidance process and to avoid providing any redundant data, which could contribute in the increase of cognitive load on the sighted guide. However, the increase in cognitive load will have an adverse impact on the overall system, and can have safety consequences on the visually impaired user. Therefore, it is useful to establish a model as a platform to conduct evaluation on sighted guide performance. In addition, same platform can be used to test different system setups to identify the best approach of system design prior to the final deployment.

CHAPTER 4

REMOTE GUIDANCE PERFORMANCE MODEL

4.1. INTRODUCTION

As mentioned in the previous chapter, it is important to establish an efficient method to evaluate the performance of the guide terminal within the context of providing sufficient important information for the guidance process, and to avoid providing any redundant data, which could contribute to the increase of cognitive load on the sighted guide. It is useful to establish a model as a platform to conduct evaluation on sighted guide performance; in addition, it can be used to establish the best guide interface for this particular application and in similar systems design prior to the final deployment, such as driving and pilot simulations, gaming and other applications. When successfully applied, the created interface setup can be used for similar applications.

4.2. The Model

The proposed model, which is shown in Figure 4.1, incorporates four main components: Guide Performance Factors, Evaluation Approach, User Preference Data and Test Scenarios. The Guide Performance Factors consists of three factors: Macro-Navigation Error Recognition, micro-Navigation Stationary Obstacle Recognition and micro-Navigation Distance Response of Stationary Obstacle Recognition. The Evaluation Approach component consists of the mathematical evaluation of the Guide Performance Factors. The following sections explain the role of each component along with their justification.

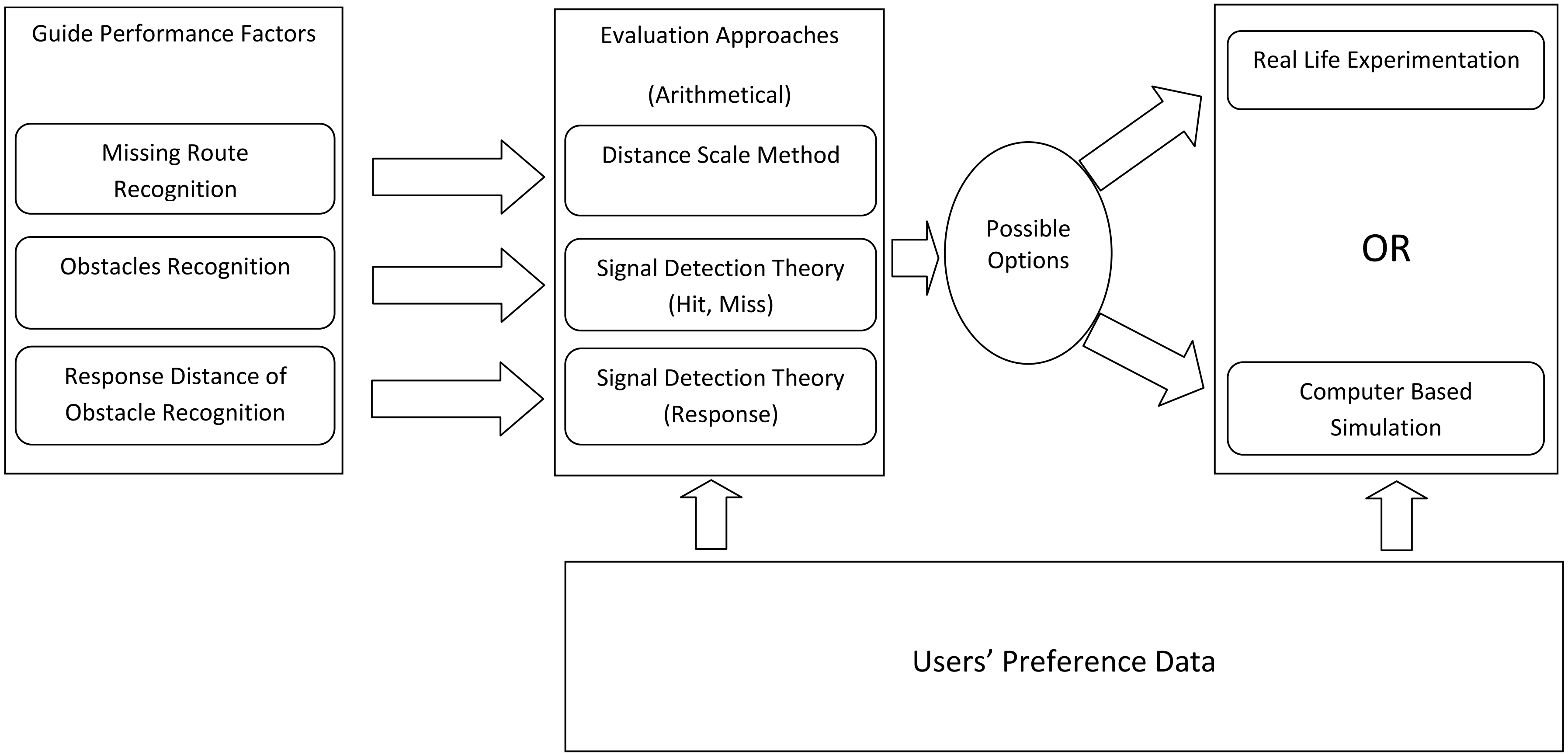


Figure 4. 1 Remote guidance performance model

4.2.1. Guide Performance Factors:

This component included the main performance factors that might impact the recognition performance of the sighted guide, as identified from the previous study (presented in chapter 3). This includes:

a. Macro-Navigational Error Recognition: while the SG is helping the users, they might be derailed onto a wrong path or miss the route, which might expose the user to some risk or make the whole process longer and more difficult. Therefore, the model should enable early detection of such situations.

b. Micro-Navigational Stationary Obstacle Recognition: one of the major roles of the SG to be able to identify the obstacles within the user's route. In addition, the SG should be able to know whether an obstacle is primary or secondary.

c. Micro-Navigational Distance Recognise of Stationary Obstacle Recognition: in order to enable the user to avoid any obstacle safely and comfortably, the SG should be able to provide prior alert at a sufficient and comfortable distance.

4.2.2. Evaluation Approaches

This component is included in order to enable the quantifying of performance factors with the use of mathematical formulas. A detailed explanation of each algorithm is given below:

a. Macro-Navigational Error Recognition (MaNE) is determined by calculating the distance between the beginning of MaNE and the recognised point when the SG realizes that the user is out of the correct route. Figure 4.2 shows the scale used to measure the performance of the MaNE of the SG. If the SG has a MaNE from the first meter, the SG will have a 100% recognition performance. However, this recognition performance will decrease 10%, eventually reaching 0% when the SG has a MaNE after 10 meters. Equation 4.1 is used to measure the single MaNE performance by subtracting the respond distance from the actual distance of the MaNE, which is 10 meters. Subsequently, 100 multiplied of the result come from the divide the response distance on the actual distance for the MaNE. Equation 4.2 is used to measure the overall performance for each participant, which includes the overall performance for all MaNE. The overall performance for each group was measured using Equation 4.3, which includes the overall performance of all participants in each group.

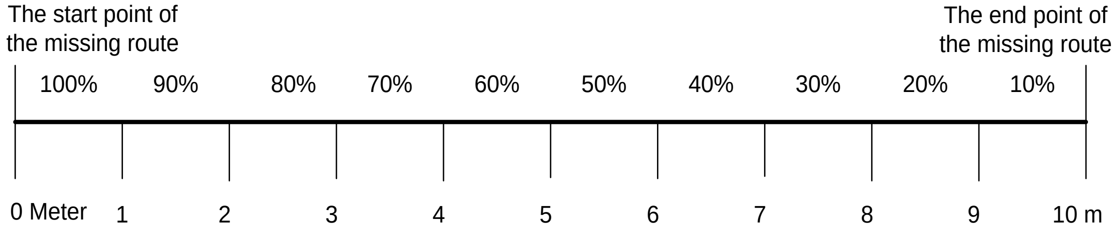


Figure 4. 2 Macro-navigational error distance scale

$$\text{MaNE\_S} = [(\text{ADMaNE} - \text{RD}) / \text{ADMaNE}] * 100 \quad \ldots\ldots\ldots\ldots \quad (4.1)$$

$$\text{MaNE\_SG} = \frac{\sum_{MaNE=1}^{NMaNE} MaNE\_S}{NMaNE} \quad \ldots\ldots\ldots\ldots \quad (4.2)$$

$$\text{MaNE\_G} = \frac{\sum_{SG=1}^{NSG} MaNE\_SG}{NSG} \quad \ldots\ldots\ldots\ldots \quad (4.3)$$

Where: **MaNE_S** = Macro-Navigational Error Recognition for single Macro-Navigational Error; **MaNE_SG** = MaNE Performance for each SG; **MaNE_G** = MaNE performance for each group of SG; **ADMaNE**: Actual distance for the MaNE; **RD** = Respond distance. **NMaNE**: Number of MaNE. **NSG**: Number of SG. SG: Sighted Guide.

b. Micro-Navigational Stationary Obstacle Recognition (MiNO) is calculated by classifying the number of MiNO that SG correctly recognized into two types, primary and secondary obstacles, then dividing the correct number of MiNO on the overall MiNO, existent in the eight test scenarios, multiplied by 100 (shown in Equation 4.4). Equation 4.5 shows the MiNO recognition performance of each group.

$$\text{MiNO\_E} = \left(\frac{\text{HMiNO}}{\text{TMiNO}}\right) * 100 \quad \ldots\ldots\ldots\ldots \quad (4.4)$$

$$\text{MiNO\_G} = \left(\frac{\sum_{SG=1}^{NSG} \text{MiNO\_}E}{NSG}\right) \quad \ldots\ldots\ldots\ldots \quad (4.5)$$

MiNO_E: Micro-Navigational Obstacle Recognition performance for Each SG. **HMiNO**: Hitting MiNO. **T**MiNO: Total MiNO. **MiNO_G**: MiNO performance for each group. **NSG**: Number of SG.

c. Micro-Navigational Distance Response of Stationary Obstacle Recognition (MiND) is based on the Signal Detection Theory (SDT) (Green, 1966). The MiND between the VIUs and the obstacle was divided into two areas, as shown in Figure 4.3. Table 4.1 shows the rate method for each area based on the SDT. Two categories were applied in Area 1, based on the response of the SG: False Alarm, if the SG reported an obstacle and the SG got a 0 point rate (for the reason that was too early to report the obstacle), which will impact the speed of the VIUs and increase the stressful feeling for them. 1 point as a Correct Rejection was given to the SG in case that they did not report an obstacle. Area 2 also has two categories: a Hit, which gives the SG one point if they reported an obstacle; and zero points, under the Miss category in case of the SG not reporting an obstacle. The percentage of the recognition performance of each SG in responding to the distance of the obstacle recognition was calculated by multiplying 100 of the result of the division of the summation of the hitting points for all eight test scenarios at the maximum point, which includes in the simulations, as shown in Equation 4.6. Equation 4.7 shows the overall performance level of the respond distance of the obstacle recognition for each group.

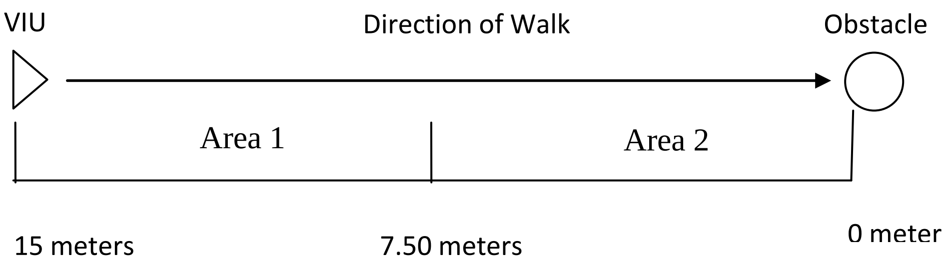


Figure 4. 3 Diagram of the two areas in relation to the MiND between the VIUs and the obstacles

Table 4. 1 MiND rating in relation to SDT

	Area 1	**Area 2**
SDT Category	False Alarm	Hit
Do Respond	0	+1
SDT Category	Correct Rejection	Miss
Do Not Respond	+1	0

$$\text{MiND\_E} = \left(\frac{\text{HP}}{\text{MP}}\right) * 100 \quad \ldots\ldots(4.6)$$

$$\text{MiND\_G} = \left(\frac{\sum_{SG=1}^{NSG} \text{MiND\_}E}{NSG}\right) \quad \ldots\ldots(4.7)$$

Where: **MiND_E =** MiND for each SG; **HP** = Hitting Point; **MP** = Maximum Point; **MiND_G =** MiND for each Group.

4.2.3. *USER PREFERENCE DATA*

This component includes a data feed that can be collected or predefined in accordance to trial needs. For example, in a test to evaluate guide performance in Central London, information reflecting a similar environment to Central London is included in the test scenarios. More details on user preference data will be presented within the design section, alongside different ways to collect the user preference data, such as classical research methods (questionnaire, interviews and literature review).

4.2.4. *TEST SCENARIOS*

In this component there are two scenarios to perform the guide performance evaluation:

i. Real Life Experimentation:

In this scenario the model will evaluate the guide performance by employing all the elements and participants in real life, including a real SG providing real guidance interaction to the user during a life journey. However, as mentioned previously, the main aim of this model is to find the SG performance, which might make a risk in case of the SG having a low guide performance level. Such mistakes might be very dangerous to the user during a journey. Furthermore, the stress level of the user will be increased if the SG has any mistakes, possibly resulting in wrong data from the user end, which wrong data might affect the guide performance. Another drawback was the long time that the user and the SG take to engage with the experiment, which inhibits having enough participants.

ii. Computer-Based Simulation:

In this scenario the model is built as a computer simulation to evaluate the guide performance in BRGS, which will reflect similar environments to real life based on the user preference data (section 4.2.3). Furthermore, the computer-based simulation will be more realistic and user-friendly, while avoiding real life experimentation problems. In this study a computer-based simulation has been employed to evaluate the guide performance. The following sections explain the phase of creating the computer-based simulation.

The methodological approach that the computer-based simulation was based on is the Waterfall System Development Life Cycle (SDLC) model (Avison & Fitzgerald, 2003). The waterfall model was chosen for its simplicity and clarity of methods, as it is widely used in commercial software development, where the requirements are well known and defined. The model consists of five different phases that are used in this research study. The phases are shown in the following Figure 4.4.

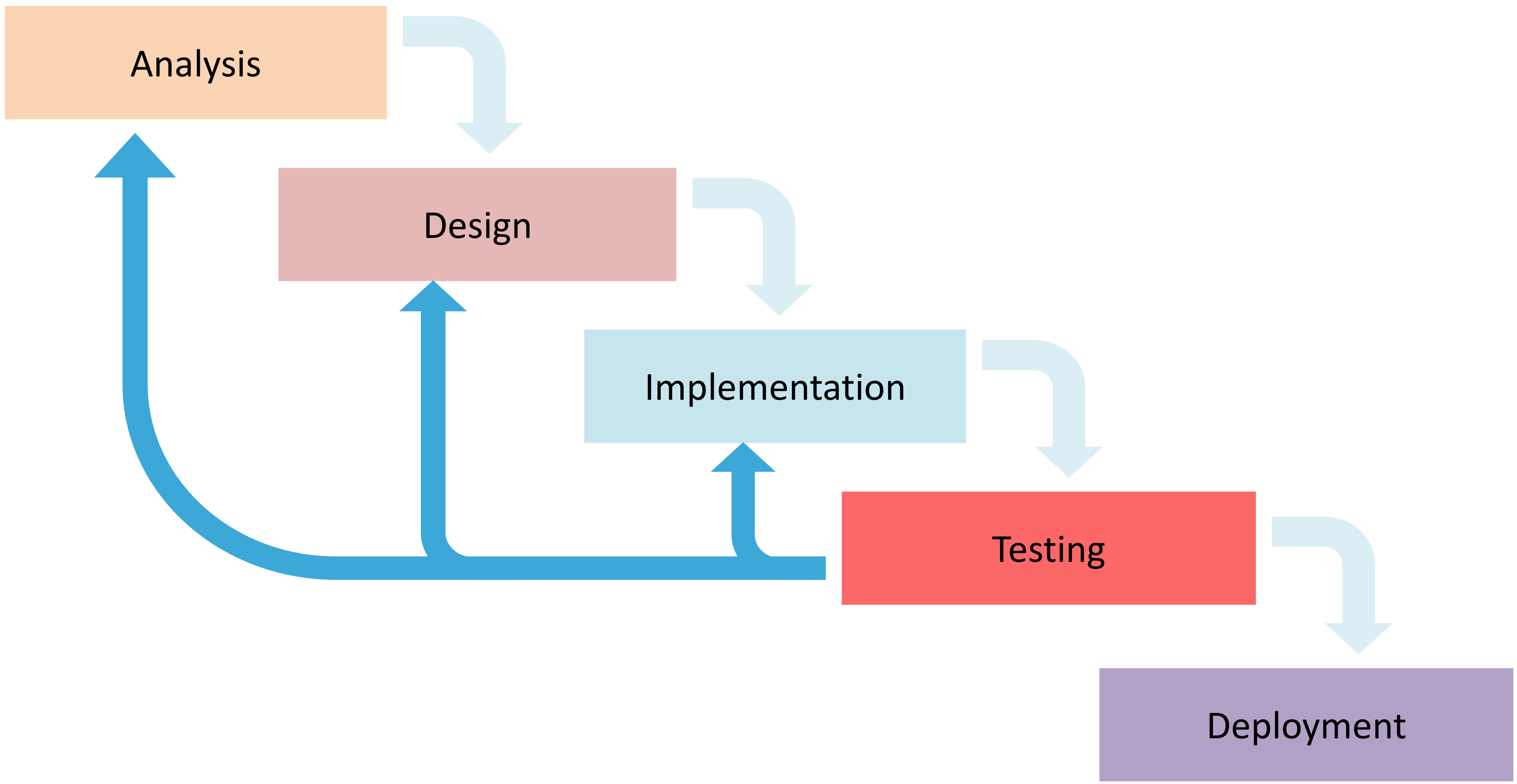


Figure 4. 4 Waterfall model (SDLS)

The following sections discuss the previous phases with respect to the research study. Each phase will discuss the methods implemented with respect to each section presented.

a) Analysis

In this phase the requirements are related to the BRGS, which has been explained previously as a case study. This section has provided the criteria used in constructing the design phase. These requirements are divided into two parts: one for the VIUs requirements and the other for BRGS requirements. The following sections explain this in more detail.

1. **VIUs Requirements (VIUs preference data):**

VIUs requirements were collected by conducting individual interviews with 4 VIUs at Brunel University. The 4 visually impaired students comprise 24% of the overall visually impaired students studying at Brunel University. Brunel University was chosen to be an experimental environment to conduct this project, therefore all the participants were chosen from the same experimental environment. The problems the VIUs faced during their journey were discussed in interviews, along with the requirements that they need to help them improve their mobility, which support the importance of BRGS.

The interview process was divided into three parts; the first part is voice recorded, which explained the general idea of the project, including a real time guidance experience of blind participants (Garaj, 2006) as a real life example. The second part was a small description that explained the main aim of this study, in order to help the VIUs to understand the interview scope and the importance of their information to improve this project. The third part included eleven questions, divided into two sections (Appendix 2).

The first section has 4 questions (Q’s 3, 4, 5, 6) to clarify the Macro-Navigational Error data that the VIUs faced during their journey. Based on the data collected from the interviews, the majority of the VIUs could go from 1 to 2 miles as a typical journey distance. During planning this journey the main challenges that they faced were to memorise street names, door numbers, the right transportation (e.g. bus number or bus stop), the direction that they need to follow once they get off the bus to reach their destination and planning safe places that they need to use to cross the street.

Furthermore, one of the major problems they also have is missing the route; they need to find someone to help them to get on the right track, which adds more time to the journey; this experience affects some of them such that they prefer to use an alternative route to avoid these problems. The final question was related to the way that they used to memorise the new route; they needed some practice to identify key points, and sometimes had to ask for a help from a sighted guide several times before they memorised the route.

The second part of the interview has 5 questions (Q’s 7, 8, 9, 10, 11) related to the Micro -Navigation Stationary obstacle and response distance of this obstacle. Different kinds of stationary obstacles were collected as data related to the most common obstacle that the VIUs could face during the delay in navigation, such as trees, groups of people standing in their path, parked cars on pedestrian pavements and pavement furniture (e.g. chairs, post boxes, rubbish bins, advertisement frames etc.). Data about other kinds of obstacles that are hard to detect by the VIUs included overhead obstacles (i.e. the obstacles descending from above the VIUs to their head level), road works, barriers and other small obstacles. In all kinds of obstacles the VIUs needed approximately 2 to 6 meters' advanced warning to know if there was an obstacle ahead to allow them to avoid it safely.

All this information will be taken in account as VIUs' preference data during the design phase, which will be useful to establish a computer-based simulation as close as possible to the real life environment, which VIUs might face during their movement from place to another.

2. Computer-Based Simulation Requirements:

The initial part of the requirements was already mentioned in chapter 3; the requirement to include guide terminal setup elements. Further requirements need to be included, which will help to establish a suitable computer-based simulation. The next section explains these further requirements in detail.

The simulation should support different screen resolutions for video image and digital map. In addition it should allow time synchronization between the video image stream and the location tracking on the digital map, as this simulation will be used for research in defining the best guide terminal setup in terms of screen resolution for both video image and digital map display.

The simulation should also be able to save and present the results data in a very simplified and understandable format, in order to be easy to understand and undergo further analysis by a wide range of users (researchers) with different backgrounds. It is useful to present the data in clear format, and it should enable automatic saving of the data into electronic format, which can ease access for future retrieval.

Moreover, the simulation should be enabled to use and design function keys to run the test, in order to avoid confusion or providing wrong recognition. The simulation should be adjustable to run different test scenarios with different time scales and different test features and variables, to maximise the utilisation of this simulation to cover a wide range of research and training activates related to BRGS. The simulation should enable the selection of different test scenarios from the test database, which is normally valid in terms of time scale and parameters.

Furthermore, the simulation should be designed to be used with easily installed and usable software (on a normal PC). For different uses of this tool it is important that it be designed using compatible and well-known SW packages, which can be easily installed and used on a normal PC, preferably with low storage requirements and open source program code. In order to track the VIUs location on the digital map, an indicator should be used to present the VIUs movement in the simulation, and the journey track should be an obvious line that connected the start point with the destination.

In case of the VIUs having a MaNE, such as a missing route or taking a wrong turn, the simulation should alert the SG by any sight alert to keep the VIUs in the right track to reach their destination. Once all the requirements of the system and the VIUs have been defined, the second phase is to build the simulation, as explained in the following section.

b) Design:

1. Screen resolution:

Based on the variations of the standard resolutions used in the international standard for 3.5G telecommunication (Richter, 2007), two screen resolutions were chosen: "Common Intermediate Format (CIF "352 x 288 pixels"; see Figure); and 4 Common Intermediate Format (4CIF "704 x 576 pixels"; see Figure). This is to present the data that comes from the VIUs on two screens - one for the digital map and the other for video image.

The combination of the guide terminal interface setup needs to involve two screens, as mentioned previously. To decide which screen resolution is suitable for this study for the two screens, an analysis was conducted to highlight the main reasons that help to make a decision based on previous research and the network limitations, which are related to data transmission. First of all, the CIF resolution was chosen as one of the screen's resolution, based on the recommendations of previous research. This study compared the smoothness and the total quality between the QCIF resolution and CIF resolution by using a participant's judgment; the results showed that there are no significantly differences between QCIF and CIF; however, the participants were more amenable to the CIF resolution (Hunaiti et al., 2006a). The second screen resolution chosen was 4CIF, which comes as a next order of the international resolution that used in 3.5G telecommunication.

The first reason is that this resolution is commonly used in certain video conferencing systems (Hunaiti et al., 2006a) ; the second is the network capacity - when comparing 4CIF resolution with the 16CIF resolution, the 16CIF needs more capacity to transmit the data resolution by using the available network, which might affect the video streaming or the digital map by the data delay or data loss during the transmission of data between the user terminal and the guide terminal. This delay and data loss might be a serious problem that the sighted guide faces when guiding the VIUs in real life (i.e. any delay or data loss resulting in delivering wrong information to the sighted guide in the guide terminal will affect the guidance instructions given to the VIUs).

However, 4CIF need less capacity, which facilitates the delivery of data with less delay and loss, will help to provide the sighted guide with optimum data, resulting in the best information provision to the VIUs during their journey.

2. Video image route and digital map

Efforts were made to find environments, which were the same as those that are faced by VIUs in their daily journeys. Each route has different number of MaNE, MiNO, duration time and environment features (e.g. pavement width, kind of MiNO, which will be explained later, and on-and-off the Brunel University campus). The reasons for the difference between the routes is to make sure that the sighted guides do not have a chance to feel bored, and to give them the chance to deal with most environmental cases that might be faced during real-life guidance.

Nine routes were selected out of 16, based on the VIUs requirements, as mentioned previously (Appendix 2). One of the routes was used as training simulation to familiarise the sighted guide with the system before participation in the study, which helped them to understand the concepts of the MiNO and MaNE as well as to get used to simulation approaches, the kind of obstacles. Any questions that they had raised related to the simulation were addressed.

Furthermore, the screen resolution for the training simulation was created based on the screen resolution for each group (Table 4.2). The other eight test scenarios were used to evaluate the sighted guide recognition performance. Each video image route has a digital map that was created by using ether Google Maps and Brunel University Digital Maps.

The MiNO is divided to two kinds; primary and secondary obstacle. The flowing explanation discusses the matter of the MiNO in detail:

I. ***Primary Obstacles:***

Any obstacle that is located in the travel path (i.e. within the boundaries of a pavement) that directly impedes the movement of the VIU's body (e.g. street furniture, traffic signs, road and pavement works, cars parked on the pavement, kerbs and steps; "VIU's body" considers the width and the height of the user, from ground level to the head). Figure 4.5 shows the primary obstacle located directly within proximity to the VIU's body.

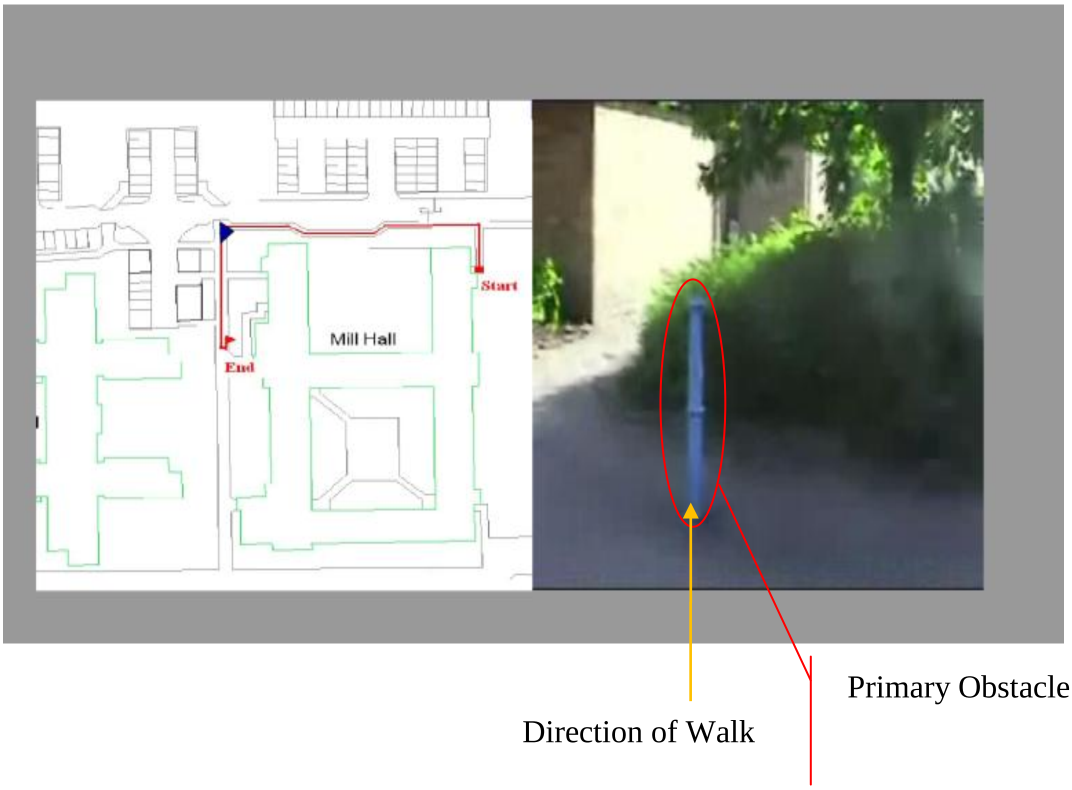
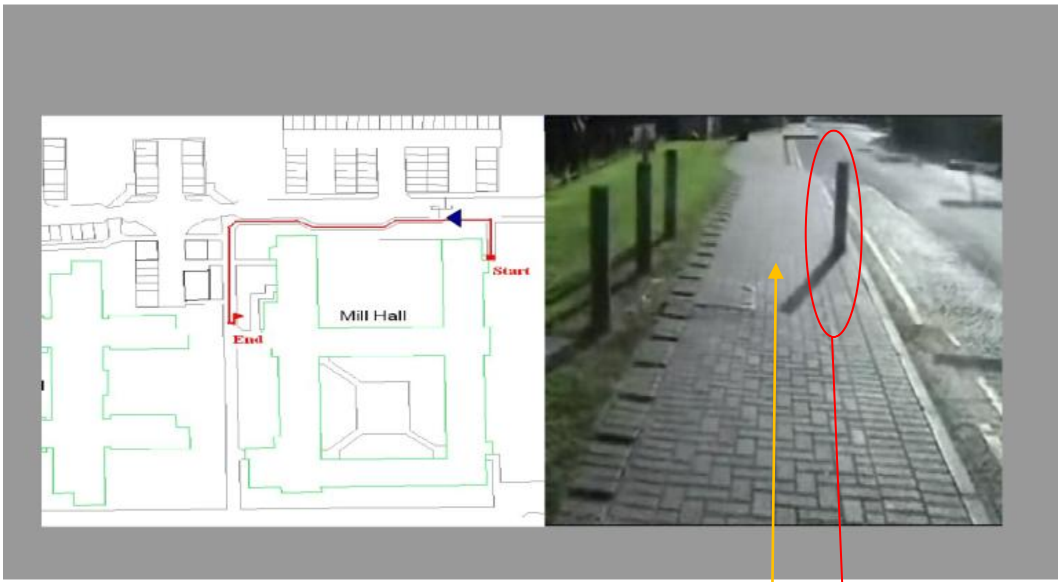


Figure 4. 5 Image for primary obstacle with the direction of walk

II. ***Secondary Obstacles****:*

Any obstacle that is located in the travel path (i.e. within the boundaries of a pavement) but it is not located directly within the proximity of the user's body, which might impede the walk if the walking direction is changed by the user. Figure 4.6 shows a secondary obstacle (located not directly in alignment with the user's body, but which could potentially become so).



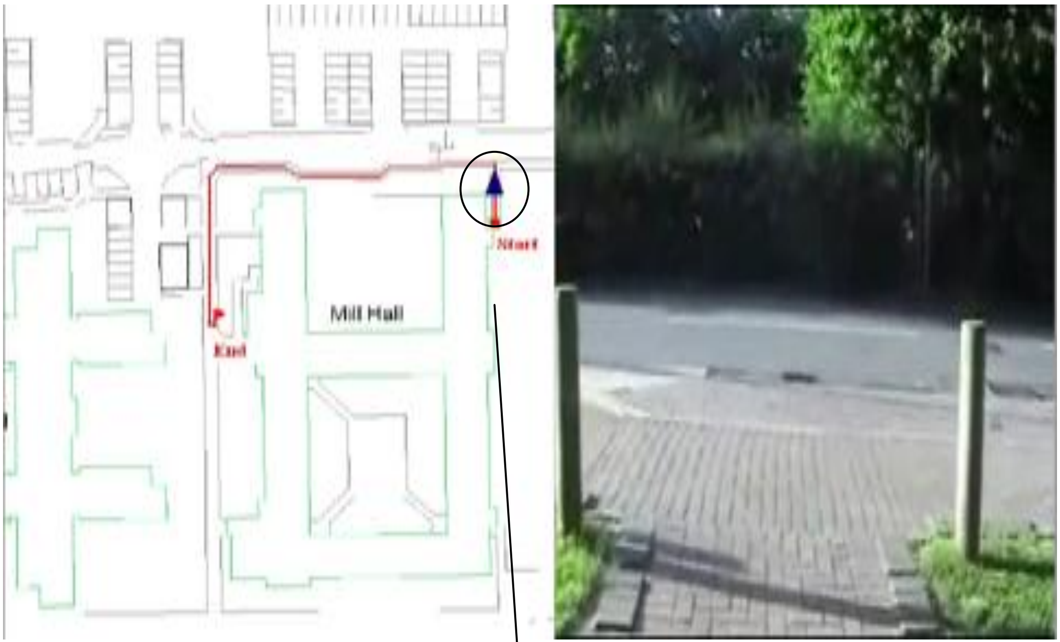
Secondary Obstacle

Direction of Walk

Figure 4. 6 Image for secondary obstacle with the direction of walk

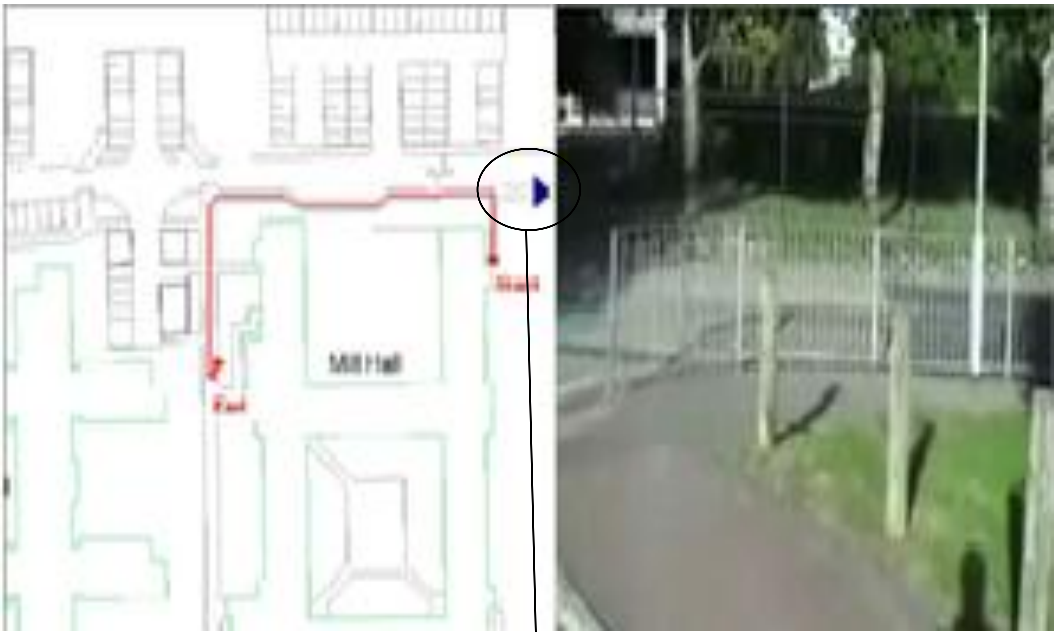
In each journey there is a path that connects the start point with the destination (end point), presented as a red colour line, which shows the path that the VIUs should follow. The path is pre-planned by the SG by using a professional updated map (e.g. Google Maps) that shows all roads, street names and road works. Any error might affect the right track of the VIUs in the wide-travel environment, such as missing the track or wrong turn (due to VIUs or the SG), called a Macro-Navigational Error (MaNE). Figure 4.7 illustrates a series of images for the wrong turn as an example of a MaNE.

1)



On the track

2)



Off the track

Figure 4. 7 Sequence of images of the macro-navigational error "Wrong Turn"

Each obstacle needs to be reported before the VIUs reach it, to ensure that they avoid the obstacle safely and comfortably. Thus, there is a right and wrong distance to report an obstacle; in other words, there is an early, right or late distance response of the stationary obstacle by the SG in the close-travel environment, called a Micro -Navigational Distance response (MiND). This MiND is important to help the VIUs avoid the obstacles, as well as to keep moving at a constant speed and without stress during their journey

3. Function Keys

The function keys have been selected based on the computer-based simulation requirements, where the key labelled "1" in the numeric keys on the right-hand side of the keyboard reports the primary obstacles, and the key labelled "2" reports the secondary obstacles on the MiNO (see Figure 4.8). The spacebar on the keyboard reports the MaNE (see Figure 4.9). All the function keys are easy to deal with, and they are reachable and simple.

Figure 4. 8 Function numeric keyboard's keys

Figure 4. 9 Function spacebar keyboard's key

4. Program language

The computer-based simulation requires a computer program language to create a computer code, which allows the synchronized movement between the video image and the digital map. This synchronised movement reflects the real life of the VIU's journey to the sighted guide as a simulation. Furthermore, the program language also needs to be very accurate to save each report of the sighted guide recognition in the exact time and distance. Off-the-shelf software programme language was used, which called Adobe Flash CS4, to create the simulations code in this study.

5. Alert

A red flashing circle alert was chosen to alert the SG if the VIUs drill in MaNE; however, the alert goes off when the distance of the MaNE goes further than 10 meters. This flashing alert will help to keep the SG's attention without being disturbed, while moving the indicator to the right track in the digital map screen, and the playing the right video image in the video image screen as shown in Figure 4.10.

Figure 4. 10 MaNE alarm

c) Implementation

Once the design phase was complete, the implementation phase was entered, in order to programme the computer-based simulation using Adobe Flash CS4 software. The following flowchart (see Figure 4.11) explains the main functionality of the computer-based simulation code, which shows the functionality of each element used in the simulation. The flowchart is divided into three stages:

1. **Input layer:**

   The input stage is to employ the requirements collected from the computer-based simulation and the VIUs to programme the simulation code. Thus, in this study, the inputs were the screen resolution, the number of the simulation (including the number of MaNE and MiNO), and distance between the obstacle and the VIUs necessary for alert (MiND).

2. **Progress layer:**

In this stage, based on the roles of the program language software, all the simulation functions were implemented in order to give the right output. These functions were to ensure that all the simulation was completed by the SG, to activate the function keys, which relates to reporting the MaNE, MiNO and MiND, and also to ensure all the requirements were achieved.

3. **Output layer:**

This is the last stage, which is responsible for saving the output form in PDF format for all the results that come out from the SG. These results were used to analyse the SG performance, the main aim of the simulation.

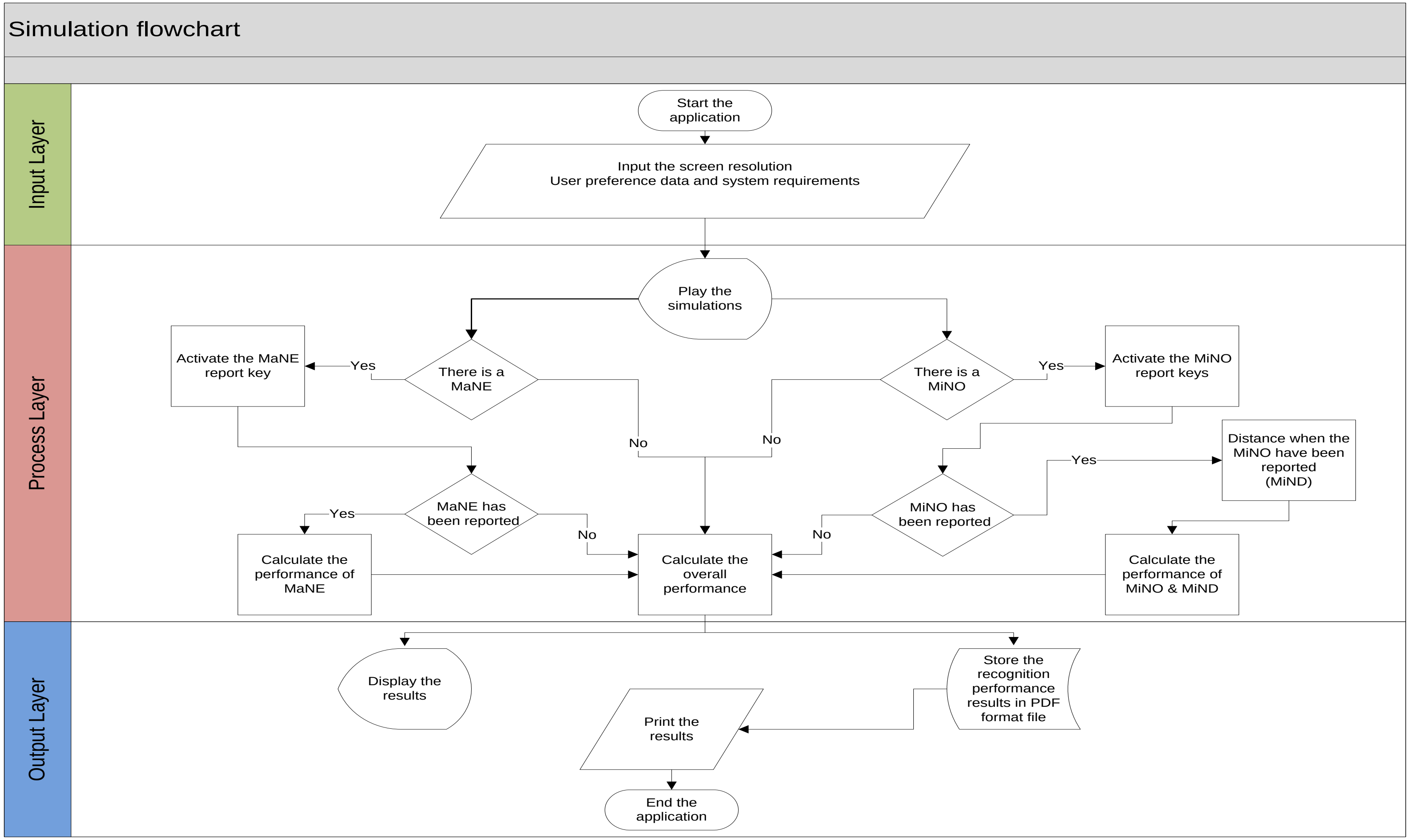


Figure 4. 11 Simulation flowchart

d) Test

The system was tested by the researcher before the pilot study occurred; the main purpose of this stage was to conduct a pilot test of the simulation before the main study was carried out in order to discover if there was any problem or shortcoming either in the simulation code or the functionality of the simulation, and to get any feedback from the participants to improve the simulation, to be suitable for them in the main study, which would have an impact on the main decisions. The following sections explain the method of the pilot test, as used in the main study (see the following chapter).

1. **Method**

In pilot test, a series of simulations were presented to the participants (i.e. SG) of the typical environment that the SG might be viewing while assisting in the (Micro and macro) navigation of VIUs during their journey (see video image route and digital map in design section in computer-based simulation in section 4.2.4.**)**. These simulations were based on the laboratory principles to be controlled. The study involved 20 sighted participants divided in four groups (G1, G2, G3 and G4), with 5 participants in each group. All participants were shown eight test scenarios that included pre-recorded video clips and pre-programmed digital map (see implementation section in computer-based simulation in section 4.2.4.).

The eight test scenarios, which the participants observed, had the same content. However, screen resolutions were different between the groups. Each group had the same combination of screen resolutions of digital map and video clip screens as illustrated in Table 4.2. The two screen resolutions were Common Intermediate Format (CIF “352 x 288 pixels”) and 4 Common Intermediate Format (4CIF “704 x 576 pixels”; see screen resolution in design section in computer-based simulation in section 4.2.4.).

Table 4. 2 Map and video image screen resolutions

Group	**Map screen size**	**Video image screen size**
Group 1	4CIF	4CIF
Group 2	4CIF	CIF
Group 3	CIF	4CIF
Group 4	CIF	CIF

2. ***Participants:***

20 participants in the pilot test were selected randomly from postgraduate students in different schools based at Brunel University. The age range and age mean as well as the male-to-female ratio were kept similar in all four groups, in order to ensure there was no difference between the groups’ parameters, which helped to avoid any negative impacts on the pilot test outcome (Wickens et al., 2004). The

Mean (M) of age, Standard Deviation (SD), age range, and male-to-female ratio of the participants in each group is shown in Table 4.3.

Table 4. 3 Age-mean and ratio value

Group	**Mean**	**SD**	**Age range**	**Male-to-female ratio**
G1	31.4	6.1	23-40	40:60
G2	32.6	6	24-39	60:40
G3	29.4	5.9	23-39	40:60
G4	31.6	8.7	25-45	60:40

3. **Procedure:**

20 individual sessions took place over a period of 4 days (5 sessions per day) in the pilot test. The running time of each session, each of which involved one participant, was approximately 50 minutes. A similar procedure was applied in all the sessions, as described below.

An introduction to the study was given in the beginning of the session to each participant. This introduction was divided into two parts: the first part was the presentation of a short video film to the participants, explaining the main aim of the BRGS, in order to help them understand the system as a real-life application, and to allow them to understand the principles of this study; the second part was a written explanation form that included the simulation procedure and principles, to ensure that all the details of the task were delivered to the participants in the same way.

Once the participants read the explanation form, a training simulation was conducted in order to help the participants to understand how to use the simulation (see video image route and digital map in design section in computer-based simulation in section 4.2.4.). In this training simulation, most of the MiNO (primary and secondary obstacles), MaNE and MiND within the boundaries of the travel path were included, to give the participant a clear vision about the main aim of this simulation, so they could recognize the MaNE, MiNO and MiND as well as practice the method of reporting these.

Furthermore, the details and number of the MaNE, MiNO and MiND included in the training simulation (duration time 2:24 min), were as follows: 3 primary obstacles (overhead obstacle, pavement and metal pillar) in MiNO and their MiND; 2 secondary obstacles (metal pillar of the barrier and rubbish bin) in MiNO and their MiND; and 2 missing routes in MaNE. The committed errors were explained to the participants after they finished the training simulation, in order to enable them to improve their performance. The screen resolutions of the training simulation were matched with the same screen resolutions based on each group.

After the training session was finished, based on the screen resolution setup, 8 test scenarios were shown to each participant in order to examine their recognition performance. The eight test scenarios were presented to each participant in a different order in each group. The participants were asked to report MaNE, MiNO and MiND for the navigation of the VIUs. The participants reported MiNO using the numeric keys in the right-hand side of the keyboard, where they used the key labelled “1” to report the primary obstacles, and the key labelled “2” to report the secondary obstacles (see function keys in design section in computer-based simulation in section 4.2.4.).

The participants were asked to report the MiND from 1 to 7.5 meters in advance based on the needs of the VIUs to avoid the obstacles (i.e. the remote sighted guides need to provide the instructions from 1 to 7.5 meters in advance to the VIUs to inform them that there is an obstacle, which enables them avoid the obstacle safely and comfortably).

Furthermore, the participants used the space key to report the MaNE (see function keys in design section in computer-based simulation in section 4.2.4.). Subsequently, the log of errors was saved as a PDF file for each scenario test. Based on the participants’ groups, each participant had a profile, which included all the PDF files for the 8 test scenarios, which helped to collect the recognition performance data for each group to use during the analysis stage.

A questionnaire was given to the participants in order to provide the researcher the feedback form after using the simulation. The participants used this questionnaire to rate themselves based on stressful, attention, monitoring two screens, ability to recognize the MaNE, MiNO and MiND, and the helpful level of training course. The questions in this questionnaire used a Likert scale (Field,

2005) from 1 to 7, in which the value of 1 (depending on the question) meant not difficult, not stressed, not hard or not helpful, and the value of 7 meant extremely difficult, extremely stressed, extremely hard or extremely helpful. The attention questions used a percentage value.

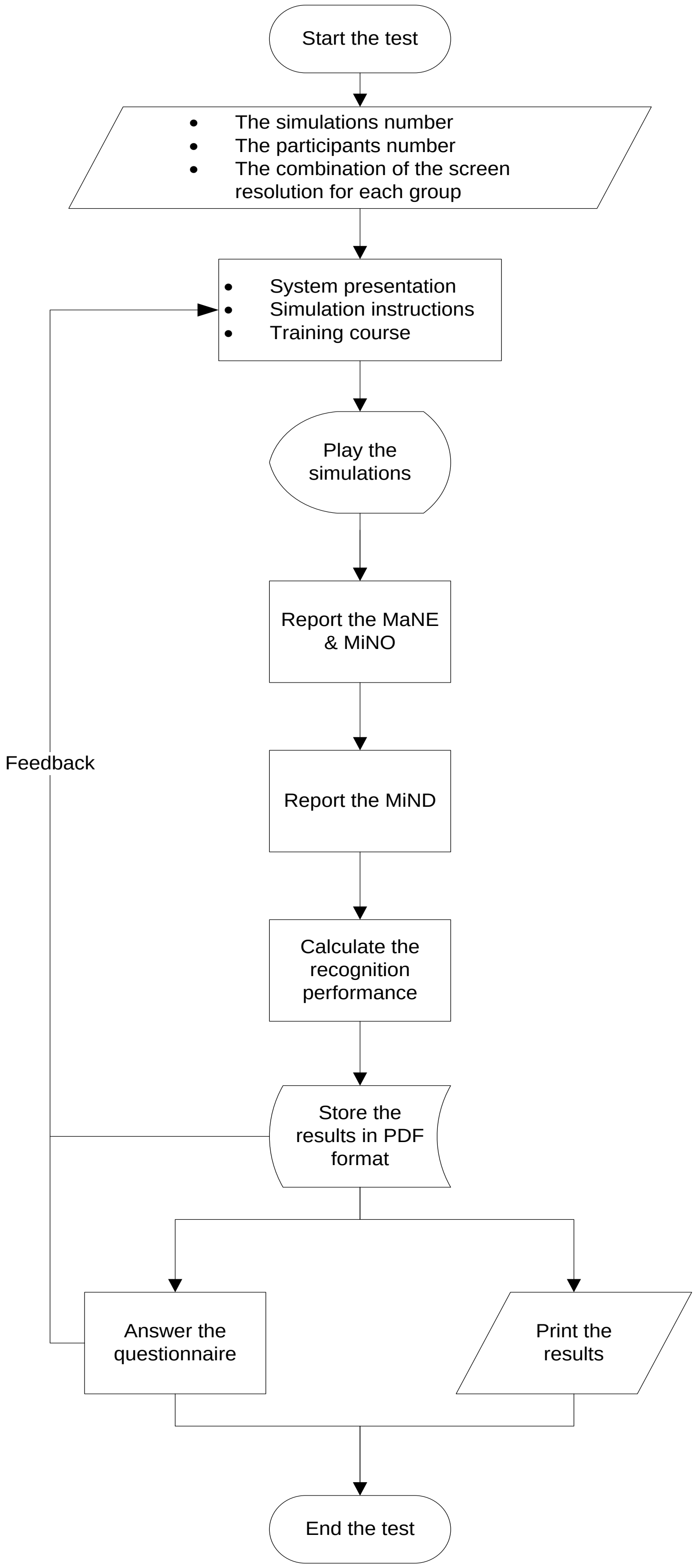


Figure 4. 12 Test process flowchart

4. Results:

The PDF files were collected and grouped based on each group (section 4.2), which included all the performance data related to MaNE, MiNO and MiND. This data was processed by using calculation methods, which related to each performance factor (see section 4.2.2), in order to be prepare for analysis. The initial analysis was done after the data was ready; all the results were positive, which indicated no shortcoming on the result side. However, different shortcomings related to improving the simulation in order to help the researcher to deal with data easily were solved before the final deployment. The shortcomings were as follows:

I. The simulation code; the pilot study recoded some code errors related to the final presentation of the data, as well as one error in simulation 1 related to MaNE that did not record the response of the participant, and the result given was the default value. However, these errors did not affect either the functionality of the code or the result. Thus all the errors were dealt with, updated and tested again by the researcher.

II. The training course; some of the participants are required further training in order to understand the mechanism of the simulation. In this case the participants were asked some quotations to ensure that they were understood the mechanism of the simulation after they finished the training course; however, if there was any misunderstanding, the participant took the training course with more explanation when they engaged with the training simulation. This repetition gave the participant more chances to ask questions, which prepared them for the main simulation.

III. The obstacles; some of the participants misunderstood the obstacle types after they read the written form that included the obstacle types definitions and explanations (see procedure in test section in computer-based simulation in section 4.2.4.), so the step which was taken to solve this shortcoming was to give more example by showing them some pictures about each obstacle type with more information, to make sure that they understood this matter in the right way.

IV. The questionnaire; after the participants answered the questionnaire, the researcher noticed that there were two questions that were unclear, based on the participants' enquiries about these questions. The researcher dealt with these questions by rewriting them in a clearer form.

V. The last shortcoming was related to some of the participants, who were not serious during doing the pilot study test; some of the result reflected that the participants completed the pilot study without concentration, which would affect the results if these results were used in analysis. However, such results were excluded by the researcher to keep the results clear and more reliable. This problem was solved by explaining importance of this study to improving the lives of people who have a disability in their life. Participants were also remunerated, to encourage them and to increase their feeling of responsibility to do the simulation test in serious manner, which also enabled the researcher to ask participants to repeat the test if necessary.

e) Deployment*:*

Once the pilot test was done and all the shortcomings were solved, the simulation was ready to be used in the main study, with confidence that results would be free from any error or unexpected effect. This stage was that of installing the final setup in the guide terminal interface, but before the final deployment; the main study results in next chapter show the optimal interface setup based on the effects of the interface setup (i.e. screen resolutions) on the sighted guide's recognition performance.

4.3. SUMMARY

Following the identification of the lack of evaluating the sighted guide performance from Chapter 3, a model was designed as a platform to conduct evaluation on sighted guide performance, summarising the main model's elements and their evaluation method. Furthermore, a computer-based simulation was chosen to evaluate the performance of the sighted guide, which was conducted based on the SDLC method. The clarifications of the SDLC phases were summarised, which were concluded by conducting a pilot test to ensure the reliability of this computer-based simulation and its readiness for use in the main evaluation in the following chapter and before deployment. All the shortcomings found after the pilot study was completed were solved, and the computer-based simulation was tested again with the new update by the researcher in order to be useful for the main evaluation. This model can be useful to use in similar projects that use the remote guidance systems such as: driving simulation and pilot simulation.

CHAPTER 5

INTERFACE DESIGN OPTIMIZATION

5.1. INTRODUCTION

The guide terminal is one of the major parts in BRGS and it is the core of the guidance service. Furthermore, it is necessary to optimise a suitable interface design on the guide terminal to enable the SG to provide efficient guidance instructions to VIUs to avoid the obstacles safely and comfortably in the Micro -navigation, as well as to keep them on the right track to reach their destination in the macro-navigation. This study is considered as an important part of the process of the BRGS development. The main aim of this study was to examine the effects of two-display screen resolutions on the SGs performance and their ability to recognize the Macro-Navigational Error (MaNE) (e.g. missing route (track) and wrong turn); the Micro -Navigational Stationary Obstacles (MiNO); and the Micro -Navigational Response Distance of Obstacle (MiND). These three terms of recognition are important to navigate the VIUs. In this study, the authors have followed the same methodology that was used in chapter 4 in the pilot study

5.2. METHOD

A series of simulations ware created of the typical environment that the SG might be viewing while assisting in (micro and macro) navigation of VIUs during their journey. These simulations were based on the laboratory principles to be controlled. The study involved 80 sighted participants divided in four groups (G1, G2, G3 and G4), with 20 participants in each group. All participants were shown eight test scenarios that included pre-recorded video clips and pre-programmed digital map (see video image route and digital map in design section in computer-based simulation in section 4.2.4.).

Each scenario test involved two screens; one for video image and the other for digital map. The video image shows pre-recorded footage of the VIUs' travel environment ahead, which could be captured by the camera in the user's terminal in the BRGS during the real-time journey of VIUs. The digital map corresponds to the video image and shows the VIUs position in the travel environment. The participants were asked to recognize and report the MaNE that appeared in the digital map by pressing the space key on the computer keyboard, as well as being asked to recognize and report the MiNO and MiND that appeared in the video clips by pressing the numeric keys in the right side of the keyboard (i.e. they were asked to press the key labelled “1” to report the primary obstacles, and the key labelled “2” to report the secondary obstacles, which have mentioned in function keys in design section in computer-based simulation in section 4.2.4.).

The eight test scenarios, which the participants were observed, have the same content. However, each group has simulations were different in screen resolutions with the other groups. Each group had the same combination of two-display screen resolutions of digital map and video clip screens as illustrated in Table 5.1 and Table 5.2. The two- screen displays resolutions “Common Intermediate Format (CIF “352 x 288 pixels”) and 4 Common Intermediate Format (4CIF “704 x 576 pixels”)”, which were chosen in this study, were based on the varying of the standard resolutions that used in the international standard for the 3G telecommunication (Richter, 2007).

Table 5. 1 The combination of the two- screen displays resolutions

Group	Digital Map Screen Resolution	Video Image Screen Resolution
Group 1	4CIF	4CIF
Group 2	4CIF	CIF
Group 3	CIF	4CIF
Group 4	CIF	CIF

Group	Two-screen displays
Group 1	
Group 2	
Group 3	
Group 4	

Figure 5. 1 The combination of the two- screen displays resolutions

5.2.1. PARTICIPANTS:

80 participants in this study were selected randomly from undergraduate and postgraduate students in different schools based at Brunel University. The participants were given £7.00 vouchers to take part in the study. The age range and age mean as well as the male-to-female ratio were kept similar in all four groups, in order to ensure there was no difference between the groups' parameters, which will help to avoid any negative impacts on the study outcome (Wickens, Gordon & Liu, 2004). The Mean (M) of age, Standard Deviation (SD), age range, and male-to-female ratio of the participants in each group is shown in Table 4.3.

Table 5. 2 Mean values and SD of the age and gender ratio

Group	**Age**				**Gender Ratio**	
	M	SD	Age Range		Male	Female
Group1	29.90	6.617	21	43	55	45
Group 2	29.20	6.229	18	39	60	40
Group 3	29.25	7.725	21	49	50	50
Group 4	28.10	6.480	19	40	45	55

5.2.2. APPARATUS:

Eight test scenarios (S.) were used in this study (S.1, S.2, S.3, S.4, S.5, S.6, S.7, and S.8), each of which had a video image and digital map. The video images in these simulations were recorded using Sony JVC GR-DV4000 video camera with a VLC video format. The eight digital maps in the simulations were taken from Google Maps and Brunel University Digital Map. Subsequently, the simulations were edited and programmed by using Adobe Flash CS4 software. Furthermore, the Adobe Flash CS4 software was used to run and present the simulations to the participants on the screen of the guide terminal of the BRGS.

Three elements were taken in account in the creation of the simulations:

a. Video clip: when the video clip was recorded, the video camera was continuously held in the position that resembles the chest position (Hunaiti et al., 2006a) with a 15 degree angle, which according to Hunaiti enables the SG to discover the environment ahead of the VIUs crossing with their body from the ground level to the head level. Moreover, during the recording, the walking speed was always kept at around 1m/s according to Garaj (Garaj et al., 2010), which reflects the average speed of walk in sighted people as well as in VIUs who travel supported by a guide dog.

b. Digital map: the digital map was programmed by including an object (this is represented in as blue triangle in Figure 4.7 in chapter 4) to represent VIUs location and their movement from the start point to the destination during the journey. The red colour line represents the VIUs track connecting the starting point with the desired destination, as shown in Figure 4.9 in chapter 4.

c. Control key: to enhance the simplicity and the SG performance, the control keys were selected to be reachable and clear “unconfused”. Whereas the spacebar key was chosen to report the MaNE and the numeric key was chosen to report the MiNO and MiND; where the key that has labelled as number 1 to report the primary obstacles in MiNO and MiND and the key labelled as number 2, to report the secondary obstacles in MiNO and MiND, as shown in Figure 4.8 in chapter 4.

The simulations presented in different screen resolutions of CIF and 4CIF were represented into Two-screen displays, one for digital map and the other for the video image. Each group has the same setup of screen resolutions, but it is different with the other groups. A series of eight test scenarios presented various environmental paths and stationary obstacles that can be encountered on a daily journey through an urban environment. Effort was spent to find and record the video images, which include most of the environmental features such as different kinds of obstacles (e.g. primary and secondary obstacles), different path widths (e.g. wide path and narrow path) and different places within and outside the Brunel University campus (Appendix 2). Furthermore, by using the Adobe Flash CS4 software, the links between the video images and the digital maps were programmed to present simultaneously the video image on the video image screen of the environment ahead and the VIUs position on the digital map screen, in order to examine the SG in a real-time environment.

Each simulation had a different number of stationary obstacles (i.e. primary and secondary obstacles) as a MiNO, missing route as a MaNE and duration, as shown in Table 3. These differences were taken into account in order to break the routine and to make sure that the participants always have a new route and different environments, to increase the concentration of the participants who may be familiar with certain routes. The majority of the primary obstacles included those that are difficult to detect by the VIUs (e.g. overhead obstacles, metal barriers, metal railings and small obstacles) when they use a long cane or a guide dog to support Micro -navigation. The total number of the missing routes is 9 in eight test scenarios; however, the duration of each missing route is similar to the others in all the simulations (10 seconds). The duration of the simulation ranges from 1:41 (S.3) min to 5:9 min (S.1). The specification of duration for each of the simulation is provided in Table 5.4. The overall duration of the footage is 25:01 min. The simulations were presented on a wide 21-in monitor made by Philips. The monitor screen was set at the resolution of 1680 x 1050 pixels while the simulations were presented. Figure 5.1 illustrates a capture of the screen with the training simulation which was used in the study. According to the International Telecommunication Union standards for video image quality assessment (Garaj et al., 2010), the viewing distance for the participants in front of the monitor was around 50 cm during the engagement in the simulations test.

Table 5. 3 Number of (MaNEs and MiNOs) in the simulations, and duration of simulations

		S.1	S.2	S.3	S.4	S.5	S.6	S.7	S.8
MaNE		3	1	0	0	2	2	1	0
MiNO	Primary	3	4	3	1	2	3	2	3
	Secondary	4	3	1	2	2	1	2	1
Duration		5:9m	4:26m	1:41m	1:45m	4:21m	3:57m	1:46m	1:56m

5.2.3. PROCEDURE:

80 individual sessions took place over a period of 16 days (5 sessions per day) in this study. The running time of each session, each of which involved one participant, was approximately 50 minutes. A similar procedure was applied in all the sessions, as described below.

An introduction to the study was given in the beginning of the session to the participant. This introduction was divided into two parts: the first part was the presentation of a short video film to the participants, explaining the main aim of the BRGS, in order to help participants understand the system in real life allow them to understand the principles of this study; the second part was a written explanation form that included the simulation procedure and principles, to ensure that all the details of the task were delivered to the participants in the same way. Once the participants read the explanation form, a training simulation was conducted in order to help the participants to understand how to use the simulation. This helped ensure that participants were familiar with the simulation, as well as to answer any questions the participants had. In this training simulation, most of the MiNO (primary and secondary obstacles), MaNE and MiND within the boundaries of the travel path were included, to give the participant a clear vision about the main aim of this simulation, so they could recognize the MaNE, MiNO and MiND as well as practice about how to report these. Furthermore, the details and number of the MaNE, MiNO and MiND included in the training simulation (duration time 2:24 min), were as follows: 3 primary obstacles (overhead obstacle, pavement and metal pillar) in MiNO and their MiND; 2 secondary obstacles (metal pillar of the barrier and rubbish bin) in MiNO and their MiND; and 2 missing routes in MaNE. The committed errors were explained to the participants after they finished the training simulation, in order to enable them to improve their performance. The screen resolutions of the training simulation were matched with the same screen resolutions based on each group.

After the training session was finished, based on the screen resolution setup, eight test scenarios were shown to each participant in order to examine their recognition performance. The eight test scenarios were presented to each participant in a different order in each group. The participants were asked to report MaNE, MiNO and MiND for the navigation of the VIUs. The participants were used to report the MiNO the numeric keys in the right side of the keyboard, where they used the key labelled number 1 to report the primary obstacles, and the key labelled number 2 to report the secondary obstacles. However, the participants were asked to report the MiND from 1 to 7.5 meters in advance based on the needs of the VIUs to avoid the obstacles (i.e. the remote sighted guides need to provide the instructions from 1 to 7.50 meters in advance to the VIUs to inform them that there is an obstacles, which enables them avoid the obstacle safely and comfortably). Furthermore, the participants used the space key to report the MaNE. Subsequently, the log of errors was saved as a PDF file for each simulation. Based on the participants' groups, each participant had a profile, which included all the PDF files for the eight test scenarios, which helped to collect the recognition performance data for each group to use during the analysis stage.

A questionnaire (appendix 2) was given to the participants as a final part of this study in order to find out the participants experience in using this simulation. The participants used this questionnaire to rate themselves based on: the level of the stressful, attention percentage between the two screen, the difficulties level of monitoring two screens, difficulties level of recognising the MaNE, MiNO and MiND, the clearness level of MiNO in the video image and the helping level of the training course. These ratings were used to evaluate the MaNE, MiNO and MiND recognition from a subjective point of view. The questions in this questionnaire used a Likert scale from 1 to 7, which the value of 1 (depending on the question) meaning not stressed, not difficult, not clear or not helpful, and the value of 7 meaning extremely stressed, extremely difficult, extremely clear or extremely helpful. The attention questions used a percentage value that the participant is paid on the digital map display and the video image display.

5.3. RESULTS

Once all 80 participants completed the study sessions, the PDF files were analysed to collect the performance data for the MaNE, MiNO and MiND. Every performance factor had its own calculation method, which was used to collect and prepare the data to be ready for the analysis, which has mentioned in section 4.2.2.

The mean values of recognition performance of MaNE, MiNO and MiND (i.e. stationary obstacles recognition, response distance of obstacle recognition) for each group are presented in Table 5.5 and Figure 5.1. The Table and figure illustrate the mean values (in the Table marked as M) and the standard deviations of the mean values (marked as SD) for the recognition performance achieved by participants in the four groups. To complete the analysis of this study, ANOVA and POST HOC analysis (Field, 2005) were carried out in order to find out if the screen resolutions of the user interface affected the performance in the MaNE, MiNO and MiND recognition task. The analysis has compared the mean of performance recognition factors between the four groups. The results of the ANOVA analysis are presented in Table 5.6 and the results of the POST HOC analysis are presented in Table 5.7.

The evolution of the recognition performance with relevance to the Micro - navigation and macro-navigation of the VIUs was investigated in this study, which has shown that there are differences in the recognition performance level between the results of the four groups. Table 5.5 and Figure 5.1 illustrate the mean values of the performance factors (i.e. MaNE, MiNO and MiND) related with the macro and the micro navigation of the VIUs, where the mean values of performance level of the MaNE is differ in Group 2 from Group 3 (10.39%) and Group 4 (8.45%). However, Group 2 has a slight difference compared with Group 1 (2.45%).

In the side of micro-navigation, which includes MiNO and MiND, the mean values of the performance level were also different between the groups. In the MiNO, Group 2 had the biggest mean value with 10.15%; Group 2 is differed by 6.08% and 7.97% from Group 3 and Group 4 (respectively). However, performance level differences between groups 1, 3 and 4 were small. On the other hand, the mean values of performance level of the MiND varied, with the greatest mean values for Group 4 and Group 2, with a small performance difference (1.35%), while Group 4 had a quite large difference compared with Groups 1 and 3 (with 15% and 15.07% respectively). In the same case with Group 2, this differed by 13.65% and 13.72% from Groups 1 and Group 3 (respectively). There was a high degree of similarity between mean values between Group 1 and Group 3, with only 0.07% difference. The mean values do not show if the differences are statistically significant or not, therefore, an ANOVA test was conducted to find out if there is any significantly difference between the groups.

Table 5. 4 The mean values of the performance factors

Category		Group1	Group2	Group3	Group4
MaNE	M	80.61	83.06	72.67	74.61
	SD	7.410	6.376	11.689	8.541
MiNO	M	68.51	79.05	72.97	71.08
	SD	12.096	8.078	13.920	10.956
MiND	M	48.72	62.37	48.65	63.72
	SD	13.833	16.755	13.934	18.551

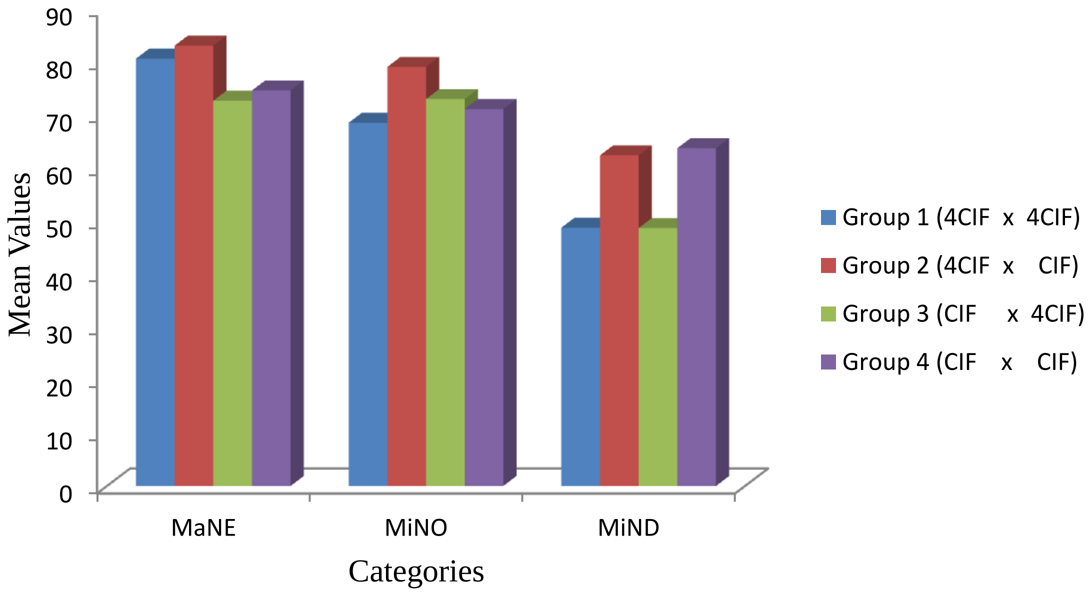


Figure 5. 2 The mean values of the performance factors

The results of the ANOVA test analysis have shown that there are also differences in recognition performance level between the participants in all the groups, as illustrated in Table 5.6. This analysis found that the differences in the recognition performance level achieved by the participants in all the groups are significant ($\alpha < 0.05$), which means that the two display screen resolutions have an impact on the level of recognition performance that is measured by the performance factors Micro and macro navigation of the VIUs. However, to complete the analysis, a POST HOC test was conducted to compare the performance results between each group with other groups to find any significant differences between the groups, as well as to determine which group had a better performance based on the screen resolution setup and recognition performance results by using a statistical analysis.

The POST HOC results are shown in Table 5.7. In MaNE, which includes the map screen, the results show that there are similarities between Group 1 and Group 2, which means that the recognition performance results differences are not statistically significant between Group 1 and Group 2. Nevertheless, the results show that the differences are statistically significant between Group 1 and Group 3 ($\alpha = 0.026 < 0.05$) as well as the results between Group 2 and both Group 3 ($\alpha = 0.002$) and Group 4 ($\alpha = 0.016$), which means the Groups that have a 4CIF Map screen resolution have better recognition performance results relevant to the MaNE than the groups that have a CIF maps screen resolution. Based on these results, the participants found that the big digital map screen (i.e. 4CIF screen resolution) allowed them to recognize the MaNE during the simulations in a short time and small distance at a higher performance level, which they achieved in Group 1 and Group 2 with 80.61% and 83.06% respectively, compared to participants who used the small digital map screen (i.e. CIF screen resolution).

Furthermore, the big digital map screen is given more information, which the sighted guide needs to gain from the distal map in a small period of time, that help the participants to pay more concentration on the video image screen with enough amount of information about the VIUs route.

On the other hand, the results of relevance to the Micro -navigation, including the video screen, are divided into two categories: one for the MiNO and the other for the MiND. The MiNO results show similarity between Group 2 and Group 3 (α = 0.342) and a small similarity between Group 2 and Group 4 (α = 0.133), but comparing Group 2 with Group 1 the results shown that there is a significant difference between these groups (α = 0.024). The main idea arising from these results is that using the same screen resolutions of digital map and video image, such as Group 1 and Group 4, gives less performance and lowers ability to classify MiNO into two kinds (primary and secondary). This makes the participants spend more attention and effort on controlling two screens during the Micro -navigation of the VIUs, which affects the performance level for them to recognize the MiNO.

The MiND illustrate that there is very high similarity between Group 2 and Group 4 (0.993), which means that the results achieved by participants in Groups 2 and 4 did not have any significant difference. Simultaneously, Groups 2 and 4 have significantly different results compared with Groups 1 and 3 (Group 2 Vs. (Group 1 (0.040) and Group 3 (0.039)) and Group 4 Vs. (Group 1 (0.020) and Group 3 (0.019))), which means that the setup of the screen resolution which has a small video image screen (CIF), such as Groups 2 and 4, gave a higher performance than the setup of screen resolution with a big video image screen, such as Groups 1 and 3. A higher performance means that participants have a better rating that they achieved by reporting the obstacle in the right distance, which is missed by the participants in Group 1 and 3.

Table 5. 5 The ANOVA results of the performance factors

Category		F	Sig.
MaNE	$F_{3,76}$ ($\alpha = 0.05$) = 6.295	6.295	0.001
MiNO	$F_{3,76}$ ($\alpha = 0.05$) = 3.067	3.067	0.033
MiND	$F_{3,76}$ ($\alpha = 0.05$) = 4.747	4.747	0.002

Based on the ANOVA and POST HOC results, the performance for the participants differed from one group to another. The main outcome of the study is that the two-display screen resolutions on the guide terminal have significant effects on the recognition performance of the sighted guide, which is proof that the hypothesis (Section 5.1) that the two screen resolutions might give a negative impact on the performance level in recognizing the MaNE, MiNO and MiND is acceptable. Making a decision about what is the best possible combination of the two-display screen resolutions depends on this hypothesis and the results, which will be used in the BRGS.

Most of the project that have mentioned in chapter 2 section 2.3, such as Drishti, NOPPA, MoBIC, Naviation and others, have not mentioned any study related to the display resolution in their project, which became one of the most important limitations. Based on the study outcome of this research, the interface design has a major impact on the overall performance of these kind of projects (remote guidance systems), which has given a low priority during the improvement process of this projects.

This outcome is supported Hunaiti et al. (2006) results, which related to the video image screen resolution, of the study that conducted to determine the most acceptable quality of the video image, which used in the remote guidance of visually impaired pedestrians. The screen resolution was CIF for the video image screen in Hunaiti study; this same outcome is found in this study, however, Hunaiti study found that there are no significant differences between using CIF resolution and QCIF resolution. This result gives the initial resolution of the video image screen to start from as mentioned in computer-based simulation requirements in section 4.2.4.2.1. In this study is also found that the optimal screen resolution for the video image screen is CIF which is significantly different comparing with 4CIF (i.e. the outcome form this study which is found that the performance of using the CIF resolution is significantly higher than the performance of the performance of using the 4CIF resolution). Based on this outcome and Hunaiti study outcome the resolution of the video image screen is limited between the QCIF resolution and 4CIF resolution, which is the CIF resolution. One more thing needs to be mentioned that the Hunaiti study is a partly related for the reason that they used just one display screen, nevertheless, in this study two-screen displays have been used to evaluate the sighted guide performance (Hunaiti et al., 2006a).

In this study the sighted guide performance has been evaluated by using the resolution of two-screen displays. Other studies have used different factors to test the performance in multiple displays or multitasking studies as mentioned in chapter 3 in section 2.4; for example, the study of Garaj et al. (2010) used a frame rate, which used as a factor to test the sighted guide performance as single task application of HCI. The results showed that there is no significantly difference in the sighted guide performance by using different frame rate (25 and 2 fps) (Garaj et al.,2010).

Table 5. 6 The BOST HOC results of the performance factors

Category	Main Group		Other groups	Sig.
MaNE	G1	Vs.	G2	0.813
			G3	0.026
			G4	0.140
	G2	Vs.	G1	0.813
			G3	0.002
			G4	0.016
MiNO	G2	Vs.	G1	0.024
			G3	0.342
			G4	0.133
MiND	G2	Vs.	G1	0.040
			G3	0.039
			G4	0.993
	G4	Vs.	G1	0.020
			G2	0.993
			G3	0.019

Once the analysis of the recognition performance of the sighted guide was done, the subjective data was analysed, which was provided by the study participants. This data used to measure the level of six elements: stressful, attention, monitoring two screens, MiNO recognition difficulty, clearness of MiNO and the helping level of the training course. Table 5.7 shows the summary of the subjective data. The table illustrate the mean values (M) and the standard deviations (SD) for each of the six ratings data for four groups as well as these results were presented in diagrammatic form, which is shown in Figure 5.3. Furthermore, The ANOVA results for these ratings data were illustrated in Table 5.9.

First element was the result that related to the participants' stress. This tested the level of the participants'' stress during the simulation; the mean for all the groups were highly similar, where, the mean values were in between the minimum value for group 1 (M=1.60) and the maximum value for group 3 and group 4 (M=1.70). This means that the participants rated themselves between moderately not stressed and slightly not stressed. The results for the second element, which were related to monitor two screens, showed that the mean values were also highly similar. Where, the mean values were in between the M=2.00 (Group 3) and M=2.60 (Group 1), which means, the participants found monitoring two screens is come between slightly not difficult to moderately not difficult. As same as the results for the third element, which were rated by the participants that the difficulties in recognise the obstacle is moderately not difficult. These results were similar between all the groups.

The fourth and fifth elements results showed that all the groups had highly similar results, were the mean value were in between M=4.70 and M=5.35 for the fourth element and M=6.05 to M=6.20 for the fifth element. This means, the participants found the obstacles were clear and the training course was moderately to extremely helpful.

Table 5. 7 The mean value for participant's experience questionnaire

Questionnaire elements		Group 1	Group 2	Group 3	Group 4
Stressful	M	2.60	2.65	2.70	2.70
	SD	0.503	0.489	0.470	0.470
Monitoring	M	2.60	2.45	2.00	2.20
	SD	13.392	1.276	0.795	1.196
Recognition Difficulties	M	1.95	1.90	1.80	1.90
	SD	0.999	0.788	0.834	0.788
Clearness of MiNO	M	5.35	5.00	5.00	4.70
	SD	0.988	1.338	1.257	1.031
Helping level of training course	M	6.20	6.20	6.05	6.15
	SD	0.834	1.104	0.945	1.089

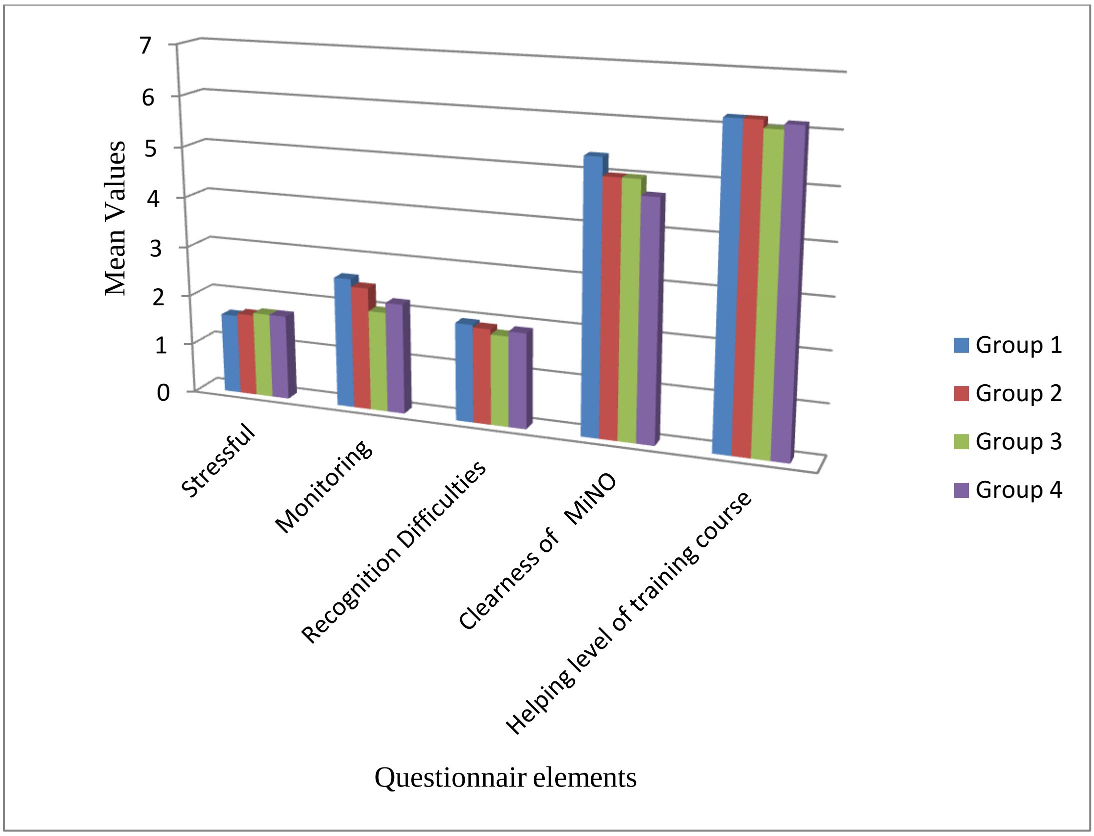


Figure 5. 3 The mean value for participant's experience questionnaire

The final element was the attention; the mean values of the attention that was paid on the two-screen displays by the participants were similar between the groups, where the mean values for the attention that paid on the digital map display and video image display were respectively in between (M=25.75 and M=34.00) and (M=66.00 and M=47.25) (Table 5.8).

Table 5. 8 The mean value for participant's attention

Questionnaire elements		Group 1	Group 2	Group 3	Group 4
Attention map display	M	25.75	27.25	26.50	34.00
	SD	13.006	12.719	11.821	10.712
Attention video display	M	74.25	72.75	73.50	66.00
	SD	13.006	12.719	11.821	10.712

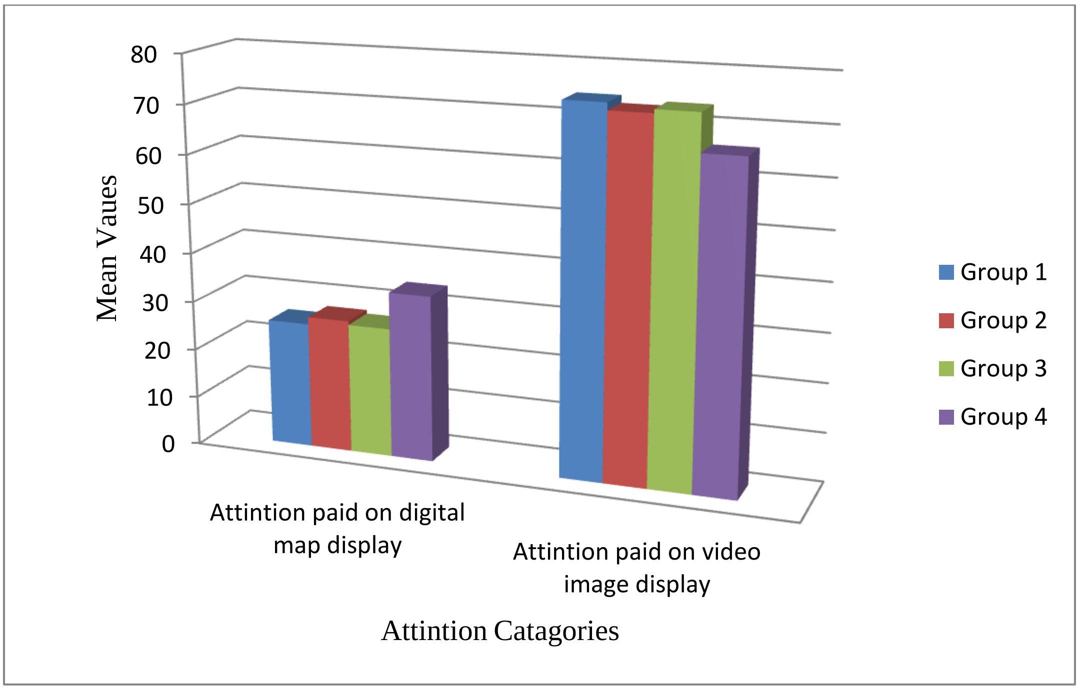


Figure 5. 4 The mean value for participant's attention

Start with the stressful, which was related to level of the stressful that the participants were felt in each group during the simulation. The results were shown a high similarity between all the groups, where α=0.899, which mean that the most of the participants rated the simulation is not stressful and that gives insignificant differences between all the groups. In addition, this result support the needs for this simulation to be used by the sighted guide before they engaged in guiding the VIUs in real word, which highly stressful comparing to the simulation that give an opportunity to the sighted guide to get used to it which will decrease the stressful during the real word.

The result that related to the attention, which the participants were paid it between the two-screen displays, is shown that there is also statistically insignificant between the four groups where $\alpha = 0.125$ (Table 5.9). However, the result shows also that the participants spent more time in monitoring the video image display than the digital map display. This support the simulation results in choosing a big digital map display, which display more information, to help the participants to gain maximum information in the short time. At the same time the result that related to the monitoring those two-screen displays is shown that the participants have no difficulties to monitoring two-screen displays. In addition, the result was insignificant between all the groups, where $\alpha=0.396$, that means that participants can handle two-screen displays at the same time with different tasks, which support the multiple display in this study. However, the simulation result is shown that even if the participants monitoring two-display screen but the is a significant result between the groups, which the size of the two-screen displays is very important to have a better performance which has mentioned previously.

In this questionnaire result also has shown that there is insignificant differences, where α=0.955, between the groups in recognising the MiNO, which they rated the recognition of the MiNO is not difficult, but there is a difference between these groups in the recognition performance, which has been found in the simulation result. Based on these results, the participants need more practice to learn how to find the MiNO and more knowledge about the MiNO types. The most of the participants have rated that the MiNO were very clear in all the video simulations, however, the results were insignificant between the groups, where α=0.378 (Table 5.9).

The efforts were spent to include all the MiNO in the training simulation to give the participants a wide experience about how to use the simulation in one hand and the type of MiNO on the other hand. All the participants groups have rated that the training simulation was extremely helpful. Furthermore the result between the groups was insignificant, where α=0.960 (Table 5.9).

Table 5. 9 The ANOVA result of the questionnaire

Questionnaire elements		F	Sig.
Stressful	$F_{3,76}$ (α = 0.05) = 0.196	0.196	0.899
Monitoring two displays	$F_{3,76}$ (α = 0.05) = 1.004	1.004	0.396
Recognition difficulties	$F_{3,76}$ (α = 0.05) = 0.108	0.108	0.955
Clearness of MiNO	$F_{3,76}$ (α = 0.05) = 1.045	1.045	0.378
Helping level of training course	$F_{3,76}$ (α = 0.05) = 0.100	0.100	0.960

Attention paid on digital map	$F_{3,76}$ (α = 0.05) = 1.973	1.973	0.125
Attention paid on video image	$F_{3,76}$ (α = 0.05) = 1.973	1.973	0.125

5.4. SUMMARY

Efforts were made to compare these two-display screen combinations in this study in order to find out the two-screen displays combination has the highest performance, greatest comfort, ease of use, less stressful, less error applied and less attention spent by the SG. However, this comparison was based on the performance of the macro-navigational error recognition on the digital map screen and the performance of the Micro -navigational obstacles and distance recognition on the video screen. In the macro-navigational error recognition the results show that the big digital map screen (4CIF) presented better results than the small digital map screen (CIF) used in Groups 1 and 2. On the other hand, the Micro -navigational obstacle and distance recognition results showed that the small video screen (CIF) presented better results than the big video screen (4CIF) used in Group 2 and 4. Thus, the combination chosen is big digital map screen and small video screen (4CIF x CIF), which is the setup of the Group 2, as a result of the joint Group “combination” between the macro- and Micro -navigational recognition to combine the big digital map screen (4CIF) and small video screen (CIF). This setup improved the SG performance during guiding and giving instructions to the VIUs to help them avoid obstacles with the safe distance and to reach their destination in the minimum time, with less effort and stress.

Based on the ANOVA test, the result that came out from the questionnaire was used to give more supports to this research to be built in real life. Some of these results were supported the simulation results. Whereas, the others highlighted some areas that need to be improve before the final setup of this project is taken a place.

Finally, the most of the result which found from this participants experience is given a proof that there is a need for this simulation as a part of this project. This also supports the model in section 4.2 to be a base in this project and similar projects. Furthermore, this simulation is a clear example about the aim of this project in the real world, which can be useful as a training course to improve the sighted guide performance in different aspects. Moreover, useful information was presented about the relationship between the two- screen displays resolutions and both the macro-navigational and the Micro -navigational, in order to give an opportunity to the researchers to improve the BRGS and to help those who have a responsibility to implement the BRGS in the future.

CHAPTER 6

CONCLUSIONS AND FUTURE WORK

6.1. CONCLUSIONS

The general purpose of BRGS is to use technology to improve VIUs' mobility based on providing guidance via a remote sighted guide to avoid obstacles and reach their destination, with enhanced safety and quality of life. The previous research work in this project showed great potential for the system through a number of experiments using a system prototype. However, it has been recommended that furtherer research is conducted to make the system more suitable to be deployed in real life.

Thus, this study builds on the development process of BRGS to improve the overall system performance; In order to achieve the main goal of this research, a suitable interface design was established on the guide terminal to enable the sighted guide to provide efficient guidance instructions to VIUs to avoid obstacles safely and comfortably in the Micro -navigation, as well as to keep them on the right track to reach the their destination in the macro-navigation. This study included a literature review, which indicated that there is still a need to use different models of EOAs in general, and BRGS in specific, which show significant improvements in VUIs' mobility.

Nevertheless, the outcomes from the literature review related to BRGS have shown that there are different elements, which could have an impact on the overall performance of the system, including the guide terminal is considered as an element in BRGS. Limited research has been undertaken on this element, which will have direct impact on the full and final deployment of the system in real life.

Therefore, it has been concluded that further steps have been taken to identify and analyse in depth the performance factors within each element with their evaluation assessment; the systematic literature review provided further support to the literature review findings related to the lack of research done on the guide terminal. The main findings that have been concluded from the analysis of the performance factors in BRGS are that there is no clear setup and performance assessment method for one essential part on the system (the guide terminal), and all the elements, with their performance factors and evolution assessments, require further research.

Hence, the solution presented to solve the earlier shortcomings is an integrated model to allow the performance assessment of the remote sighted guide simulated, which was very useful in the last phase in this research project. The main function for this model was established a solid base to test the sighted guide performance using the two-screen resolution as an input, and seeing the effect of that on performance; however, this model can be useful for different inputs in other studies, such as to test the frame rate with a two-screen resolution, or to test the recognition reaction in the human factor area. This model also helped to identify the characteristics of sighted guides capable of using this system.

Moreover, the constructed model has been used in determining the effects of the two-screen resolution “standard resolution” of the video image screen and the digital map screen on the recognition performance of the sighted guide in the guide terminal. A simulation technique was carried out in both the macro-navigational error and the micro-navigational stationary obstacles and response distance. The main outcomes showed that the effects of the two screen resolutions on the performance of the sighted guide are statistically significant, which affects the overall performance of BRGS. In addition, the outcomes of this study showed that the SG performance is improved when guiding and giving instructions to the VIUs to help them avoid obstacles, with a safe distance to avoid obstacles and to reach their destination in the minimum time, with less effort and stress.

In summary, the overall information was presented in this research work related to the critical analysis of the BRGS, performance assessment model of the remote guidance and the relationship between the two-screen resolution and both the macro-navigational error recognition and the Micro -navigational obstacle and distance recognition, in order to afford opportunity for researchers to improve the BRGS as well as to help those who have a responsibility to implement the BRGS in the future. Furthermore, the findings can be beneficial for the success of the system, as well as being a milestone on the way to further progress.

6.2. FUTURE WORK

Further works need to be conducted on the system of Brunel Remote Guidance System, in order to lead to the optimum system setup and functionality to be used in the real life as well as to improve the overall performance. Following is a summary of the further work:

1. Compass

It is important to improve the sighted guide performance by exploring other available new technologies such as ‘Digital Compass’ to improve the accuracy and usability of remote guidance systems, such as integrating the digital compass in the user’s terminal to aid navigation information. This will help the sighted guide to know the initial heading for the users, and to recognise if there is any change in the route during guiding the users to their destinations. The improvements will involve a digital compass and a mobile phone consolidated in one device, explained in detail below, thus reducing the equipments carried by the user. A custom programmed code transmitting the location data of the user to the guide terminal should use a digital compass to help the guide assist the VIU, and increase accuracy. In addition, this cardinal direction data will aid the sighted guide to identify the heading coordinate of visually impaired user, such as, North, South or etc. Moreover, the cardinal directions data will be reduced the guidance mistake that the sighted guide might face through the guidance information is given to the visually impaired user during the journey.

2. Using mobile unit in the user terminal

The new system should include the new mobile unit generation in order to be used in the user terminal, which includes the main user terminal elements (see section user terminal in section 3.5.1). However, the main idea for that is to have a lighter weight used by the users, as well as consolidating the system elements in one device. In addition, other elements should be added to enhance the functions of the mobile unit, such as power supply, to support longer running time to the mobile unit during the journey. Two function keys should be included; one to restart the mobile unit in case of the system stops working, and one to redial, which helps to establish a new video call if there is any cut in the calling process during the journey (additionally, voice-recognition redial would be useful). These function keys should be simple and easy to use for VIUs.

3. Video shaking

Based on the participants' feedback; the video image streaming needs to be improved to be more clear (i.e. the video image has not affected by the user body 'shaking'). During the footage journey, because the camera was placed on the body, the movement of the body produced shaking on the video image streaming.

Thus, there is a need to solve this problem by reducing the shaking at the source, by designing a devise to stabilise the mobile unit or camera; or removing it by creating software that uses the average of the images to give a video with a minimum effect of shaking. This will increase the guide concentration and performance to support remote guidance interactions during the journey.

4. Moving obstacles

This research concentrates on the stationary obstacles, which have a zero speed movement. However, further research needs to be conducted on the dynamic obstacles. The dynamic obstacles are: any obstacle that might affect the user movements, whose speed movement is not zero, in direct effect (primary obstacle; see the design section in computer-based simulation in section 4.2.4.) or indirect (secondary obstacle; see the design section in computer-based simulation in section 4.2.4.). This needs to be developed by analysing the different elements of the dynamic obstacle, such as obstacle speed, size, type and user speed. Furthermore, the guide performance can be measured by inputting the new elements into the model (see section 4.2). However, this needs to be measured carefully, based on the speed of the user and the obstacle, and the distance between them, as well as the size and type of the obstacle.

5. Real time

The system needs to be tested in real time with the new interface setup, which will give an opportunity to compare the sighted guide performance between the real-time experiment and the computer-based simulation. Furthermore, this will help to show the capability of the sighted guides while they guide the user in real life, and identify any weaknesses. More training courses need to be given to the sighted guides, to improve their ability to guide the users and keep them safe. The training courses should cover all the cases that the user might face during their journey, and the way to deal with these cases by supporting the users with right instructions to avoid obstacles. Moreover, the training course should be extended to cover all the obstacle types, including stationary and dynamic obstacles, as well as the ability to help the user building the right mental map by giving them clear and simple interactions. This skill needs to be improved by comparing the actual case with the sighted guide's explanation of it.

6. Using two-screen resolution in other fields

This study could open a new direction to researchers in different sciences such as psychology and human-computer interaction, taking into account the impacts of screen resolutions on human attention, which affects human performance in a variety of situations. As well as the implications of this for real-life applications, psychologists' insights into these impacts would be valuable in improving the design on systems using two-screen resolution to make them more applicable in human applications.

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APPENDIX 1: LIST OF PUBLICATIONS

- **Journal**

  - **Al-Masarweh**, M. Garaj, V. and Balachandran, W. (2011) "**A study of Performance Factors in a Brunel Remote Guidance System**". International Journal of Handheld Computing Research (IJHCR). (**In press**).

  - **Al-Masarweh**, M. Garaj, V. and Balachandran, W. (2011) "**The Effects of Two Stimuli on the Recognition Performance of the Sighted Guide**". Systems, Man, and Cybernetics part A: Systems & Humans. IEEE. (**Submitted**).

- **Conferences**

  - **Al-Masarweh, M.** Garaj, V. and Balachandran, W. (2011) **"The Effects of User Interface Screens Size on the Wrong Turn Recognition Performance in Using Remote Vision to Navigate Visually Impaired Pedestrians".** DEIT conference (Data Engineering and Internet Technology), Indonesia.

  - **Al-Masarweh, M.** Garaj, V. and Balachandran, W. (2011) **"The Effects of Screen Resolutions in Assessing Recognition Performance of the Sighted Guide".** ResCon'11, 4th Annual Research Conference, 20-22 June 2011, Brunel University, London, UK.

- **Posters**

    - **Al-Masarweh, M.** and Garaj, V. (2011) **"Effects of Display Resolution on the Visual Recognition Performance".** Graduate school conference, 15 March 2011, Brunel University, London, UK.

    - **Al-Masarweh, M.** Garaj, V. and Balachandran, W. (2011) **"The Effects of Two-Display Resolution on the Recognition Performance of the Sighted Guide".** ResCon'11, 4th Annual Research Conference, 20-22 June 2011, Brunel University, London, UK.

APPENDIX 2: REMOTE GUIDANCE SIMULATION: MATERIALS

1. Simulation tasks instruction

The following form is the tasks instructions form, which was given to the participants in the first stage of the test to help them in understanding the main aim and the simulation procedures of this project.

Task Instruction:

This study will test the obstacles detection performance for the guide person, which will help to find out the optimum design for user interface on the guide terminal. Moreover, this study will help to improve the performance for the Brunel Remote Guidance System.

This study has eight test scenarios each simulation has two screens (map and video). Different videos and maps will be shown in each simulation. The map will show the track of the user from the start point reaching the destination. Furthermore, this track has been programmed to reach the destination so no needs to use the keyboard navigation button to control the movement during the journey

The video screen will represent the video footage that might be received from the user's environment a head. These videos have been captured by walking in real world. The following is a brief for the two tasks:

The task is divided into two parts as follow:

- First part is to detect and report different kinds of obstacle by using the numeric keys. These obstacles are positioned in the travel path with the user's body (e.g. stairs, pavement, overhead obstacles, and other). These kinds of obstacle have been divided to two categories as follow:

  1. **Primary obstacles**: defined as: the environmental features with the potential to obstruct the user's walk that are positioned in the travel path directly with the user's body from the ground level up to the level of the user's head (Figure 1) (e.g. street furniture, traffic signs, walls, hedges, road and pavement works, cars parked on the pavement, kerbs and steps). To report this kind of obstacles, you should press the 1 button in numeric keys on the right of the keyboard.

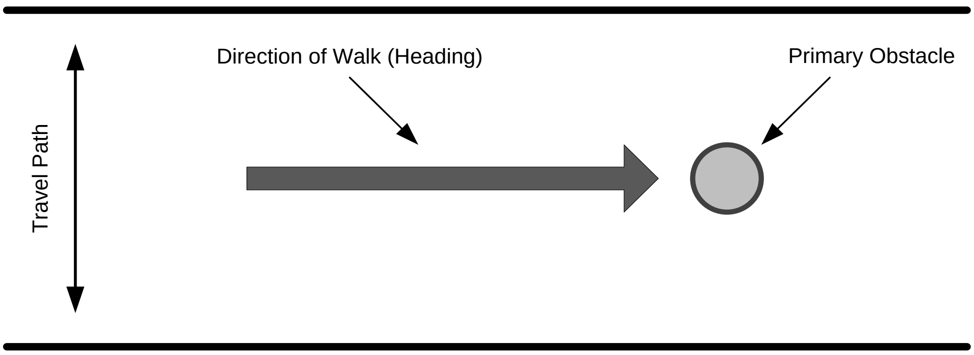


Figure 1- Primary Obstacle

  2. **Secondary obstacles**: defined as the Environmental features with the potential to obstruct the walk that are positioned in the travel path, but not necessarily directly with the user's body (the obstruction may occur if the user suddenly changes the walking direction) (Figure 2).

3. Moreover, to report this kind of obstacles, you should press the 2 button in numeric keys on the right of the keyboard.

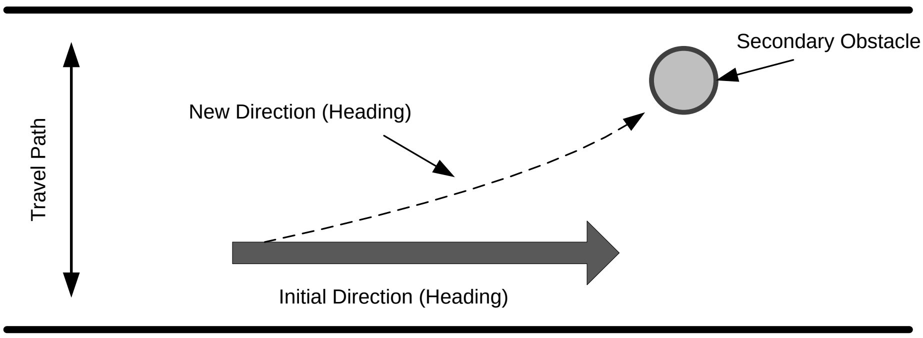


Figure 2- Secondary Obstacle

- Second part is to report the wrong root, which the user might go through it by mistake. This task will help to test the response time for the sighted guide person through the journey. Furthermore, to report wrong root you should press the space button on the keyboard.

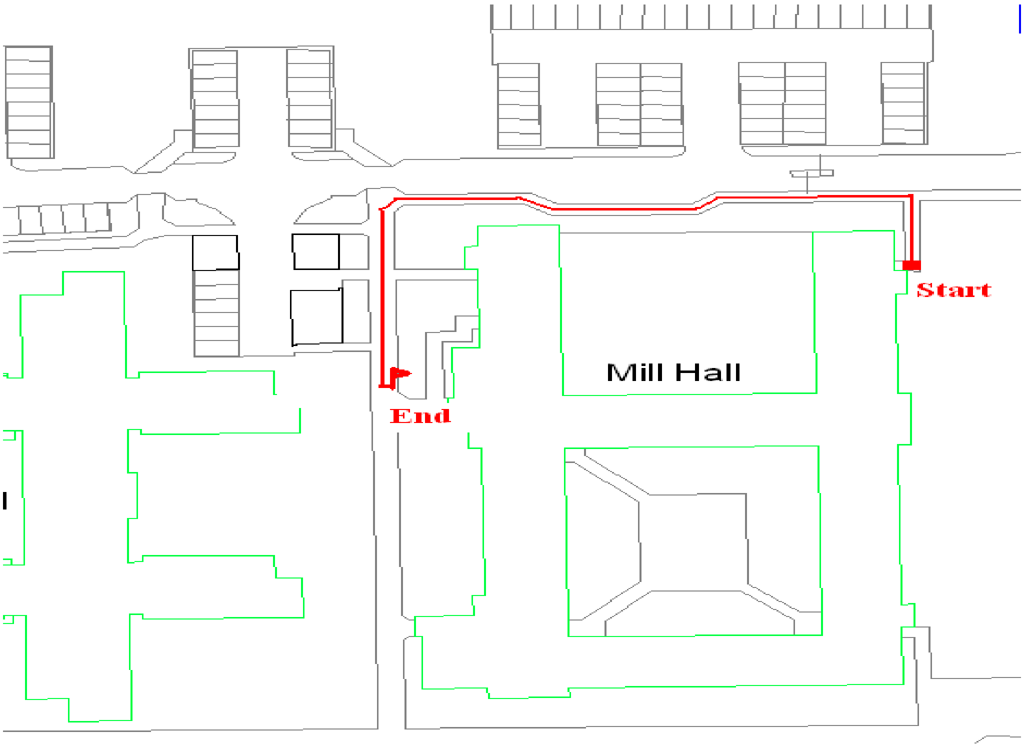
  A training simulation will be presented that provides a further description of the categories. Furthermore, this training simulation will teach the user the way for using the keyboard in this simulation.

  As an additional task in the study, you will answer a questionnaire, which will concentrate on the simulation and the feedback.

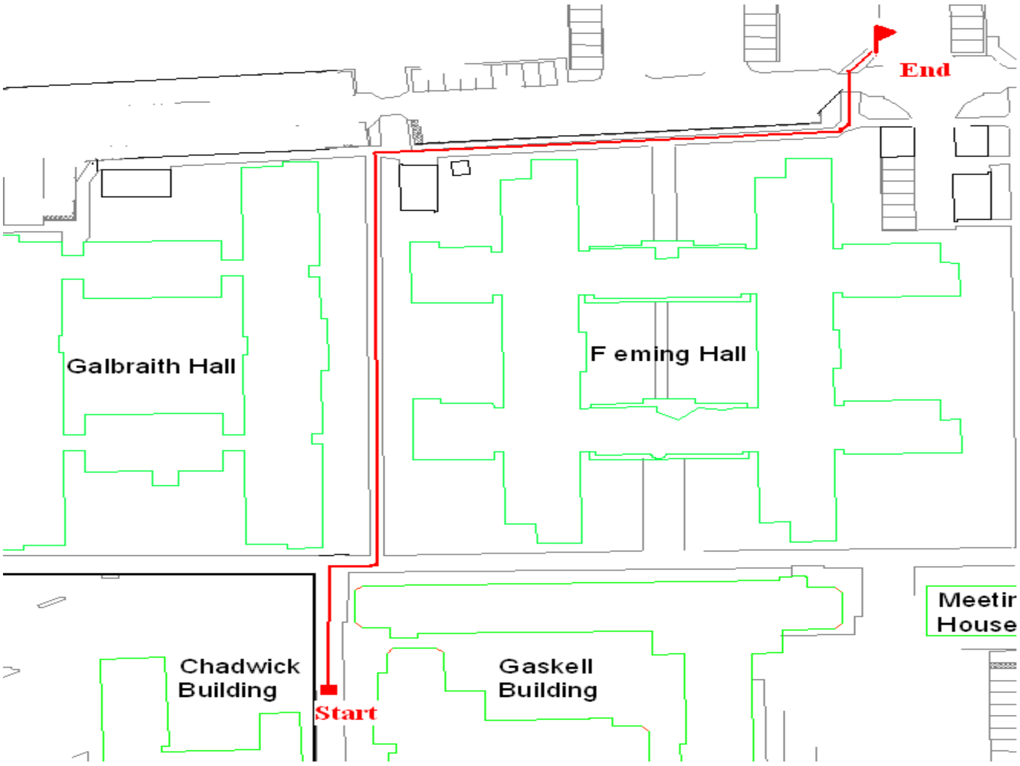
Thank you very much for your time

The nine following figures showed the all the routes that used in the simulation, which have taken from the Brunel University digital map and Google Maps.

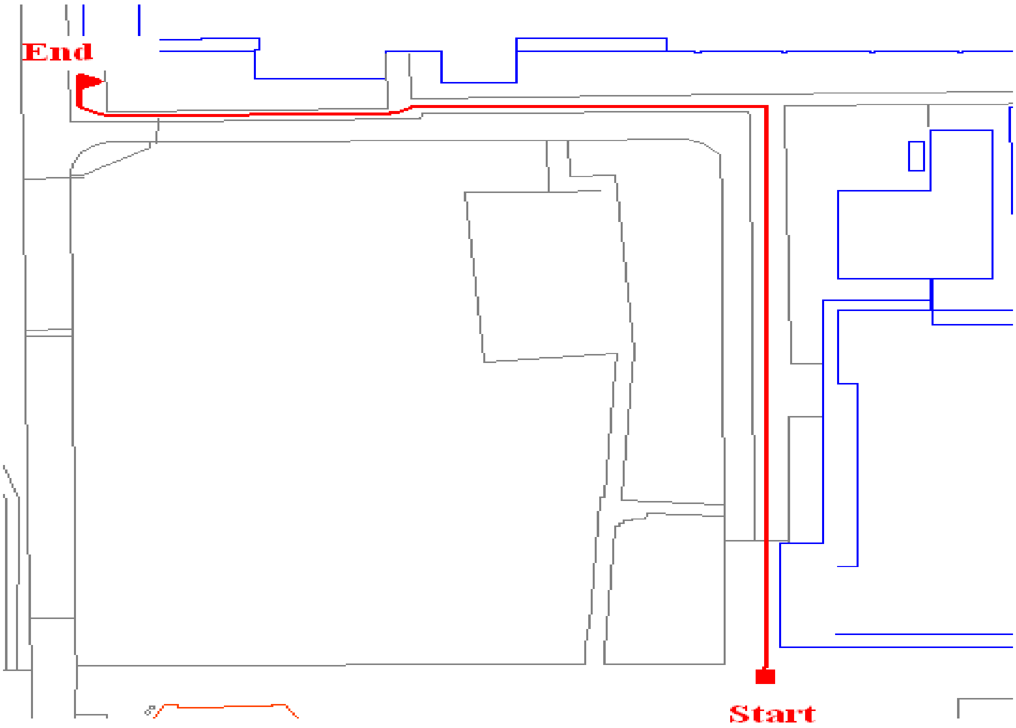
- Training course route



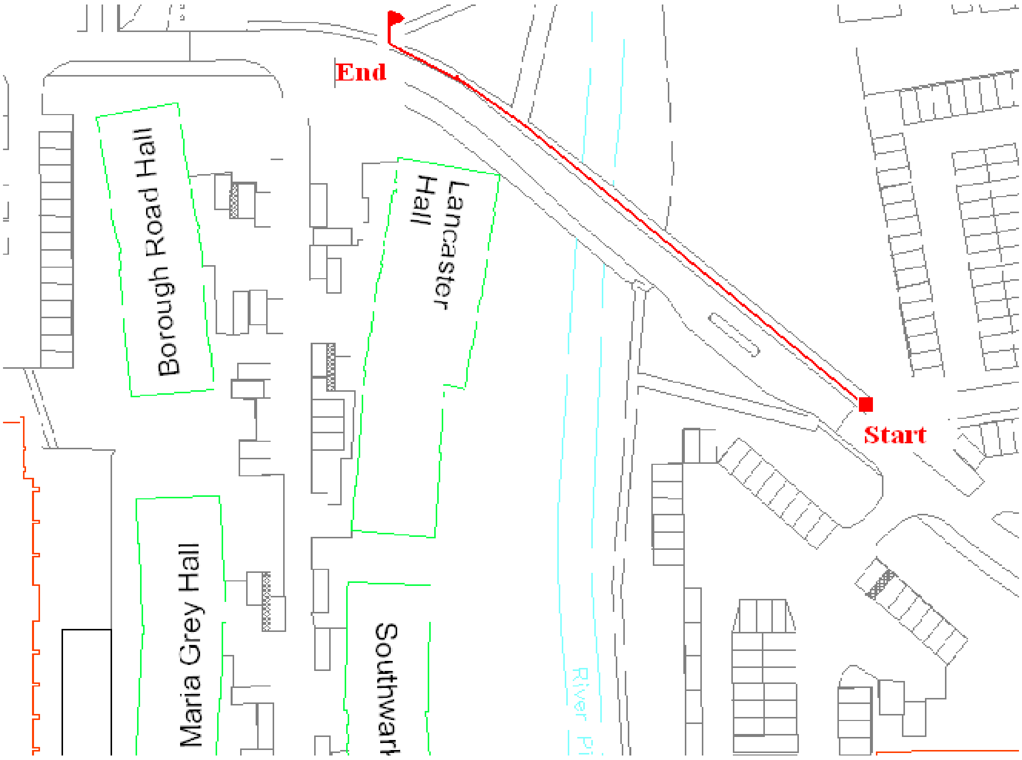
- Simulation 1 route



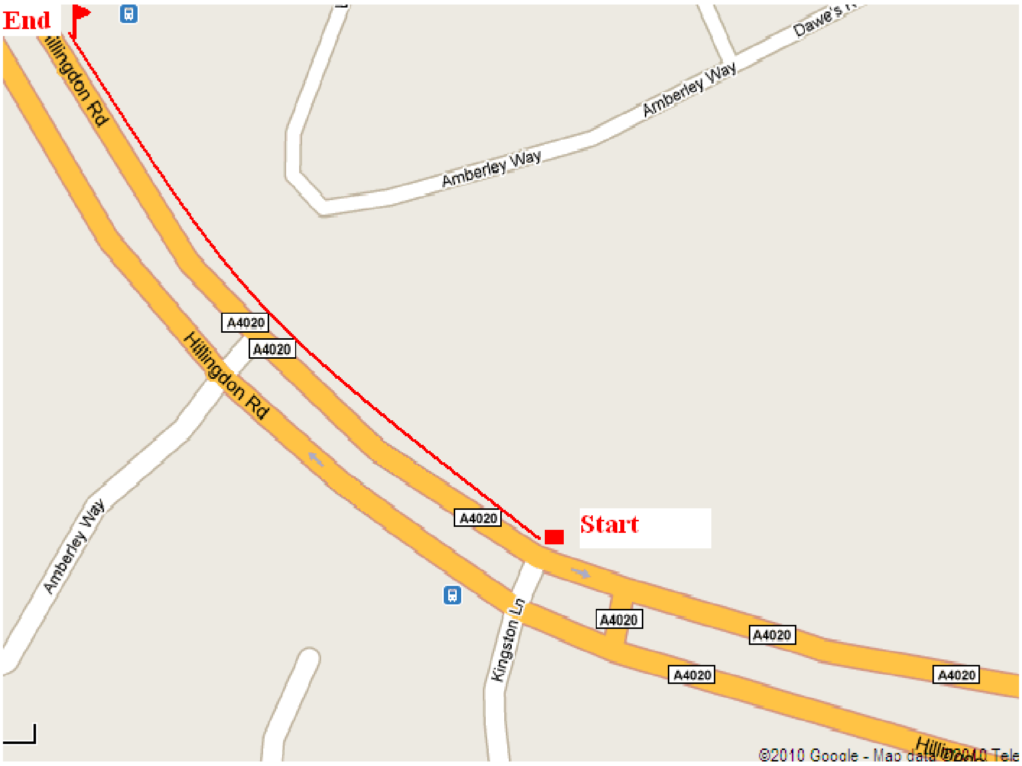
- Simulation 2 route



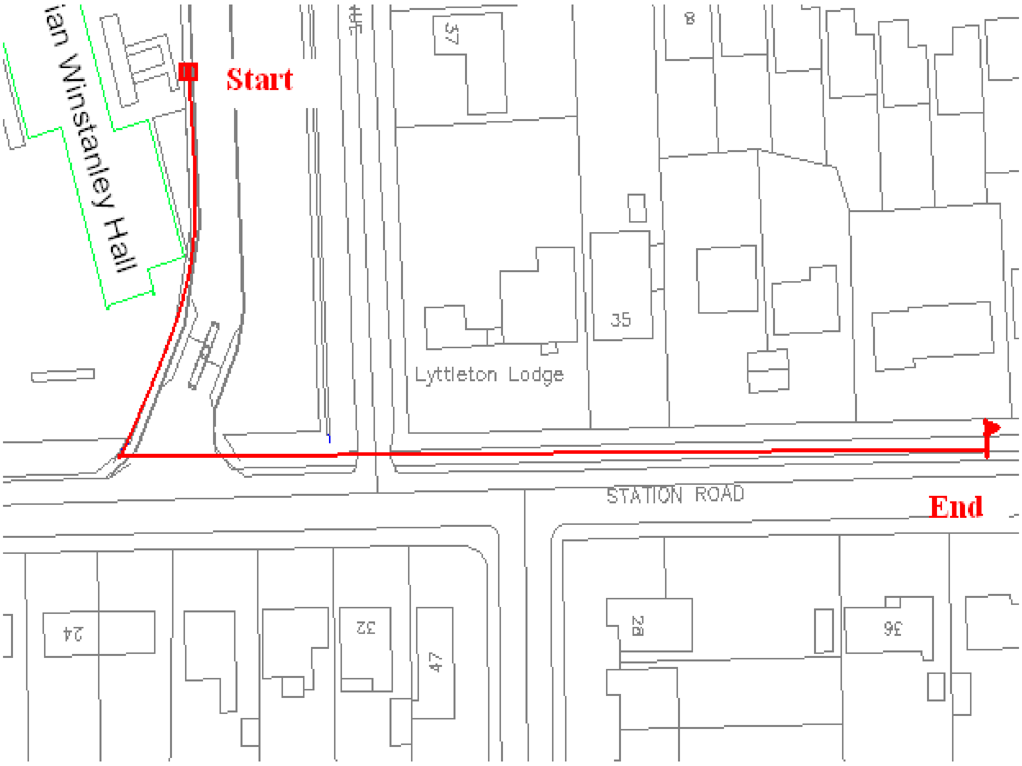
- Simulation 3 route



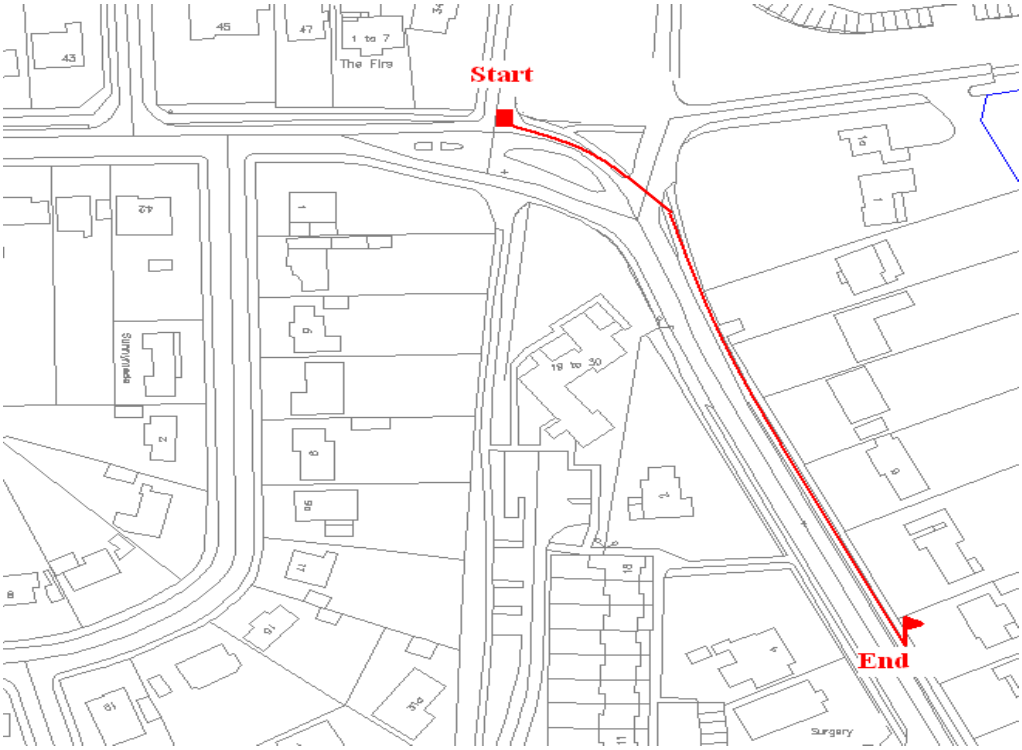
- Simulation 4 route



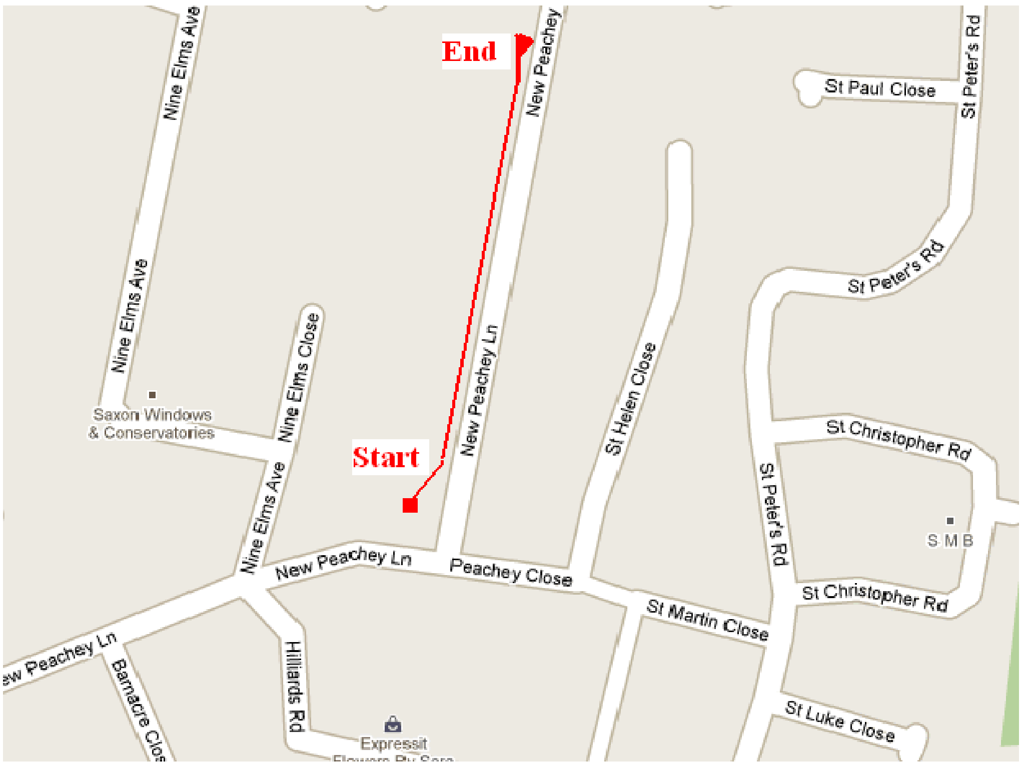
- Simulation 5 route



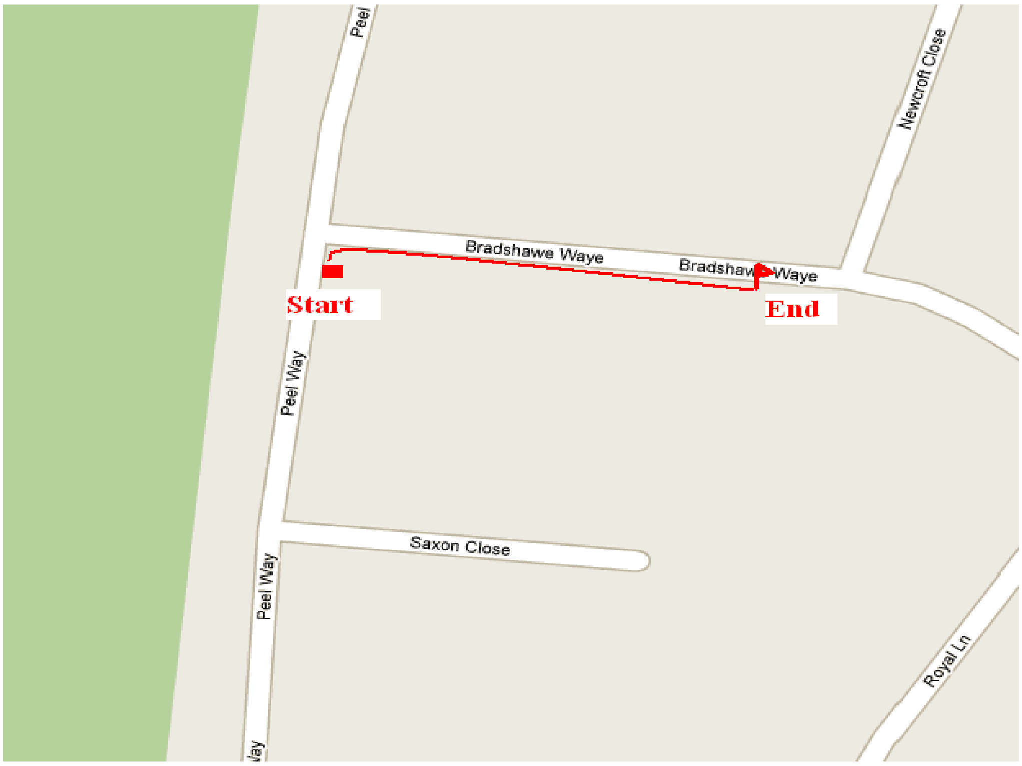
- Simulation 6 route



- Simulation 7 route



- Simulation 8 route



2. Participants questionnaire

Sighted Guide Questionnaire

Dear participant,

This short survey is designed to collect your constructive feedback about the simulation (experiment) that you have participated on. This feedback will be used to improve the tool.

Based on what you have experienced in the simulation, please tick ☑ the option that best represents your answer to the following questions:

1. How stressful did you feel during the simulation? (Indicate from 1 to 7 where one means extremely not stressful at all and seven means extremely stressful)

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

2. How difficult did you find in monitoring two screens?(Indicate from 1 to 7 where one means extremely not difficult at all and seven means extremely difficult)

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

3. Out of 100%, how much attention you have paid on the map and on the Video?

- Map (……..………..%)
- Video (……..………..%)

4. How difficult did you find in recognition obstacle (s)?(Indicate from 1 to 7 where one means extremely not difficult at all and seven means extremely difficult)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

5. Have you found the obstacles clear in the video? (Indicate from 1 to 7 where one means not clear at all and seven means extremely clear)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

6. Did the simulation training help you to use this tool? (Indicate from 1 to 7 where one means not helpful at all and seven means extremely helpful)

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

7. In the space below, please write any comments or suggestion you might have.

Your gender is

☐ **Female**

☐ **Male**

Your age is…………..

Thank you very much for your co-operation!

3. Interview questions of visually impaired people

Interview Questions

Introduction: The main aim of this project is to help visually impaired people to be mobile. The instructions will be remotely provided by a sighted guide to assist the visually impaired people to navigate them. My main research is to establish the suitable interface design on the guide terminal that will increase the performance guidance process of the sighted guide. In this phase, further information need to be collected from the visually impaired people to help us to include it in the simulation. Answering the following questionnaires will help us to collect the required information.

1. Age:
2. Gender:

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1. What kind of aids do you use to navigate through the journey?

2. Are you satisfied with using other aids to navigate?

3. How long is the longest route you are going?

4. What are the main challenges you face while planning the journey?

5. What are you doing if you miss the route?

6. How do you recognise the obstacles during memorise a new route?

7. What are the most common obstacles you face during the journey?

8. Which kind of obstacles you find them difficult to be avoided or detected?

9. Does the obstacle size affect you during detecting the obstacle on your journey?

10. What will happen if you find a new obstacle in the route, which is already memorised in your mind?

11. How many meters do you need to avoid an obstacle before you reach it?

Thank you very much for your co-operation!