Virtual Reality Technology for Blind and Visual Impaired People: Reviews and Recent Advances

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Abstract. Virtual reality technology enables people to become immersed in a computer-simulated and three-dimensional environment. In this chapter, we investigate the effects of the virtual reality technology on disabled people such as blind and visually impaired people (VIP) in order to enhance their computer skills and prepare them to make use of recent technology in their daily life. As well as, they need to advance their information technology skills beyond the basic computer training and skills. This chapter describes what best tools and practices in information technology to support disabled people such as deaf-blind and visual impaired people in their activities such as mobility systems, computer games, accessibility of e-learning, web-based information system, and wearable finger-braille interface for navigation of deaf-blind. Moreover, we will show how physical disabled people can benefits from the innovative virtual reality techniques and discuss some representative examples to illustrate how virtual reality technology can be utilized to address the information technology problem of blind and visual impaired people. Challenges to be addressed and an extensive bibliography are included.

Keywords: Virtual reality, assisitive technology, disabled people, mobility system, computer games, accessibility of e-learning.

1 Introduction

Virtual reality technology is the use of graphics systems in conjunction with various display and interface devices to provide the effect of immersion in the interactive three dimensional computer-generated environment which is called a virtual environment. Virtual reality and environment applications

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covers a wide range of specific application areas, from business and commerce to telecommunications, entertainment and gaming to medicine. It is a multidisciplinary technology that is based on engineering and social sciences, and whose possibilities and progress largely depend on technical developments. In accordance with hardware and software, virtual reality enhances the involvement of the user in a more or less immersive and interactive virtual human experiment [49].

Virtual reality refers to the use of interactive simulations to provide users with opportunities to engage in environments that may appear and feel similar to real-world objects and events and that may engender a subjective feeling of presence in the virtual world. This feeling of presence refers to the idea of being carried into another, virtual world. Virtual reality is of special interest for persons with disabilities showing dysfunction or complete loss of specific output functions such as motion or speech, in two ways. First, disabilities people can be brought into virtual scenarios where they can perform specific tasks-either simply to measure their performance such as duration or accuracy of movements or to train certain actions for rehabilitation purposes. Second, virtual reality input devices like a data glove, originally developed for interaction within virtual environments, can be used by disabled people as technology tools to act in the real world [5, 6].

Recently, more virtual reality applications have been developed which could minimize the effects of a disability, improve quality of life, enhance social participation, and improve life skills, mobility and cognitive abilities, while providing a motivating and interesting experience for children with disabilities. One of the main deprivations caused by blindness is the problem of access to information. Virtual reality is an increasingly important method for people to understand complex information using tables, graphs, 3D plots and to navigate around structured information.

Spatial problems can also be experienced by children with physical disabilities that limit their autonomous movement. Due to this, they are not likely to be able to fully explore environments, which is also a problem for those who need some form of assistance. They may also have limited access, and may rely on their assistant to choose routes. Studies on cognitive spatial skills have shown that children with mobility limitations have difficulty forming effective cognitive spatial maps [3].

This chapter investigates the effects of the virtual reality technology on disabled people, in particular blind and visually impaired people (VIP) in order to enhance their computer skills and prepare them to make use of recent technology in their daily life. As well as, they need to advance their information technology skills beyond the basic computer training and skills. Moreover, we describe what best tools and practices in information technology to support disabled people, such as deaf-blind and visual impaired people in their activities such as mobility systems, computer games, accessibility of e-learning, web-based information system, and wearable finger-braille interface for navigation of deaf-blind.

This chapter has the following organization. Section (2) reviews some of the work that utilize the intelligent mobility systems for blind and visually impaired people. Section (3) introduces the accessibility of e-learning including Visual impairment categories, its considerations and requirements for the blind people. Section (4) discusses the wearable finger-braille interface for navigation of deaf-blind people. Section (5) discusses the computer games for disabled children including audio games/sonification and tactile games. Section (6) discusses the web-based information system. Finally, challenges are discussed in Section (7) and an extensive bibliography is provided.

2 Mobility Systems for Blind and Visually Impaired People

Disability people needs to become as independent as possible in their daily life in order to guarantee a fully social inclusion. Mobility is a persons ability to travel between locations safely and independently [4]. Blind mobility requires skill, effort and training. Mobility problems for a blind person can be caused by changes in terrain and depth; unwanted contacts;and street crossings (which involve judging the speed and distance of vehicles and may involve identifying traffic light colour). The most dangerous events for a blind or partially sighted person are drop offs (sudden depth changes, such as on the edge of a subway platform) and moving vehicles [4]. Making unwanted contact with pedestrians is also undesirable as it can be socially awkward and may pose a threat to a persons safety.

Mobile and wireless technologies, and in particular the ones used to locate persons or objects, can be used to realize navigation systems in an intelligent environment[7]. A wearable system presents the development of an obstacle detection system for visually impaired people, for example. The user is alerted of closed obstacles in range while traveling in their environment. The mobility system can detects obstacle that surrounds the deaf people by using multi-sonar system and sending appropriate vibro-tactile feedback, which, serves as an aid by permitting a person to feel the vibrations of sounds. It is known as a mechanical instrument that helps individuals who are deaf to detect and interpret sounds through their sense of touch.

Such system works by sensing the surrounding environment via sonar sensors and sending vibro-tactile feedback to the deaf people of the position of the closest obstacles in range. The idea is to extend the senses of the deaf people through a cyborgian voice interface. This means that the deaf people should use it, after a training period, without any conscious effort, as an extension of its own body functions. It determine from which direction the obstacles are coming from. Localization on the horizontal plane is done by appropriate combination of vibration according to the feedback of the sensors [14].

This section will introduces the fundamental aspects of wireless technology for mobility and reviews some of the work that utilize the intelligent mobility systems for blind and visually impaired people.

2.1 Wireless Technology for Mobility

The radio virgilio/sesamonet is information and communication technologies system intends to improve blind and low vision users' mobility experience by coupling tactile perceptions with hearing aids. To this extent, wireless technologies including radio frequency identification (RFID) and Bluetooth, hand-held devices (PDA), smart phones, and specific system and application software for mobile device including text-to-speech and database are combined together[8].

Radio virgilio/sesamonet provides a suitable audio output helps the autonomous mobility of blind and visual impaired people. It has the following features:

- keeps the people inside a safe path;
- provides information about turns and obstacles on the path
- checks the right direction
- provides general and specific environmental information on demand
- provides on-line help and assistance via global system for mobile communications

Atri et al. in [7] and Ugo et al. in [8] developed and designed RFID system to help blind and visually impaired people in mobility. The system shows a disabled interaction with the system simultaneously using three different devices: a RFID Cane Reader, a PDA, and a Bluetooth headset. Together with the tag grid, they constitute the physical architecture of the system. The RFID cane reader reads the tag ID and sends this number, via Bluetooth, to the PDA; the PDA software associates the received ID to mobility information and, after converting it in a suitable message, sends it to the headset. Radio Virgilio/SesamoNet software runs on any Windows CE based portable device having a Bluetooth antenna to communicate with the RFID cane. The system interface contains the following modules:

- **Bluetooth connection manager** which keeps the BT connection channel open between the RFID reader and the PDA for tag ID string transmission.
- **Navigation data interface** it retrieves navigational data from a local database, providing the navigation logic with extended data related to a tag ID.
- **Navigation logic interface** which is the core software which handles navigation and tag data in order to provide the user with mandatory safety-related or on environmental navigation information. It also checks if the direction is right and not reverted. This module tells the user he/she is probing the central tag or one on the right or the left hand side of the path.

We have to note that, the user is not supposed to perform any task when navigation session starts or the BT manager is resumed after any loss of connection with the cane and it can send a text string containing more complex navigation or environmental information to the text to speech component.

Focussing on this problem, many successful works have been addressed and discussed. For example, Gerard and Kenneth in [1] describe an application of mobile robot technology to the construction of a mobility for the visual impaired people. The robot mobility physically supports the person walking behind it and provides obstacle avoidance to ensure safer walking. Moreover, the author summarize the main user requirements for robot mobility and describe the mechanical design, the user interface, the software and hardware architectures as well. The obtained results was evaluated by mobility experts and the user.

The ability to navigate space independently, safely and efficiently is a combined product of motor, sensory and cognitive skills. This ability has direct influence in the individuals quality of life. Lahav and Mioduser in [2] developed a multi-sensory virtual environment simulating real-life space enabling blind people to learn about different spaces which they are required to navigate. This virtual environment comprises two module of operation:(a) Teacher module and (b) Learning module. The virtual environment editor is the core component of the teacher module, which includes 3D environment builder; force feedback output editor; and (c) audio feedback editor. While, the learning module includes user interface and teacher interface. The user interface consists of a 3D virtual environment, which simulates real rooms and objects and then the user navigates this environment. During this navigation varied interactions occur between the user and the environment components. As a result of this interactions the user get haptic feedback through environment navigates. This feedback includes sensations such as friction, force fields and vibrations.

3 Accessibility of E-learning for Blind and Visually Impaired

Vision, of the body's five sensory inputs, is the essential sense used in learning. Vision also modifies or dominates the interpretation from the other senses where there is variance between the inputs from more than one sense [22]. Low vision and totally blind students must rely on input from physical senses other than sight; however, most e-learning environments generally assume the learner has sight [20]. Considering e-learning, simulations, active experimentation, discovery-learning techniques, questioning with feedback, video, animations, photographs, and practical hands-on skills, can be utilized for virtual teaching [23]. This may be the case for sighted students; however, vision impaired students do not have the sight needed to access many of these multi-media sources of delivery. Lack of accessibility in the design of e-learning courses continues to act as an obstacle in the learning way of students with vision impairment. E-learning materials are predominantly vision-centric, incorporating images, animation, and interactive media, and as a result students with severe vision impairment do not have equal opportunity to gain tertiary qualifications or skills relevant to the marketplace and their disability [20, 21].

This section presents an overview with addition to introducing considerations and requirements in order to obtain accessible e-learning environment for blind and visual impaired people.

3.1 Visual Impairment Categories

The term vision impairment refers to a vision disability resulting in little or no useful vision [19]. There are different eye conditions, which can affect sight in various ways. These conditions include short- and long-sightedness, color blindness, cataracts, which is responsible for almost half of all cases of blindness worldwide, and the world's leading preventable cause of blindness that is known as glaucoma [19].

A useful distinction can be made between the congenitally blind (those who are blind from birth) and the adventitiously blind (those who developed blindness later in life, perhaps as a result of accident, trauma, disease, or medication). There is a significant difference between these two visual impairment groups. For example, learners who have been blind from birth may find it more difficult making sense of tactile maps than adventitiously blind learners. That's due to the fact that learners who have been blind from birth have not previously acquired spatial awareness through visual interaction with their environment. Also, the degree of visual impairment can vary considerably. Generally, the range of impact can run the entire scale from total blindness through low vision to minor impairment. A broad distinction is usually made between blind people and partially sighted people. These two groups may exhibit rather different study patterns and difficulties, and may require different kinds of support [19].

3.2 E-learning Accessibility Considerations

There are two vital aspects, namely technological and methodological, to be taken into consideration for obtaining a fully accessible e-learning environment [20]. For technological issue, the most frequently used network technologies in e-learning are email and the Web. Because email is the most used communication service on the Internet, it is very useful to include it as part of any e-learning environment. Although email presents no significant problems for users with disabilities, some research proposes techniques for improving email accessibility [20]. Likewise, the web is the most used tool for accessing information on the Internet and it is the best solution for distributing educational material for e-learning. Producing a document overview is one of the main issues to be considered in an application for surfing the Web, which has a vocal interface.

Regarding methodological issue, the content interaction, in an educational context designing, is extremely important in order to reach a learning goal. Moreover, in online learning the methodology is crucial. For example, a tool may meet technical accessibility requirements, but it may be unusable for a blind student because it is designed with a visual interface in mind. Likewise, the design of a lesson could be perfect if it is delivered using a multimedia system, but may be poor if it uses adaptive technologies like a speech synthesizer. Therefore, it is very important to redesign traditional pedagogical approaches by integrating information, virtual reality and communication technologies into courses [20].

3.3 Web Accessibility Requirements for the Blind People

The web design considerations which meeting several requirements in the web development process and improves web accessibility for all blind web users. These consideration are (1) Assistive technologies for blind people, such as screen readers, have plain interfaces that sequentially express in words Web content in the order it is structured in the source code [25, 26]. Therefore a text only version of the entire website can improve the access speed for blind users, (2) Web designers should provide a text alternative for every visual element (textual description that conveys the same function or purpose as the visual element) and avoid elements that cannot be presented in this form [27, 62, 25] so that screen readers can adapt text into audio formats for the blind users to access, (3) Skip navigation links [24] enable users of screen readers to skip repeated or peripheral content and go straight to the main content. This saves time and improves usability for the blind [29], (4) Web designers should mark up different sections of Web pages with predefined semantics (such as main, heading, navigation and adverts) [26] in order to make it possible for blind people to navigate to different sections of the website including the ability to skip certain sections, (5) Designers should identify table headers in the first row and first column. Complex data tables are tables with two or more logical levels of row or column headers. They can be made accessible by associating heading information with the data cell to relate it to its heading [28, 62], (6) Frame elements should have meaningful titles and name attributes explaining the role of the frame in the frame set. Alternatively, designers can provide alternative content without frames [26, 63], (7) Web designers should explicitly and programmatically associate form labels with their controls (e.g. place text information for text entry fields and put the prompt As the blind Web users rely on keyboards as their primary input device, designers have to be sure that all parts of a Web application are usable with keyboard only access. for a checkbox or radio button to the right of the object). For forms used for search functionality, designers should ensure that results from the search are accessible with the keyboard and screen reader for the functionality. and (8) As the blind Web users rely on keyboards as their primary input device, designers have to be sure that all parts of a Web application are usable with keyboard only access.

The development of the web content accessibility guidelines by the World Wide Web Consortium (W3C) and the Section 508 standards for the federal government were both guided by universal design principles. The web content accessibility guidelines tell how to design Web pages that are accessible to people with disabilities. More recently, in response to the Section 508 amendments, the access board created standards to be used by the federal government to assure the procurement, development, and use of accessible electronic and information technology, including Web pages. Some institutions that sponsor e-learning programs that are not strictly required to comply with Section 508 adopt the Section 508 standards or W3C's guidelines. Others develop their own list of accessibility requirements for their programs [31].

4 Wearable Finger-Braille Interface for Navigation of Deaf-Blind People

Globally, deaf-blindness is a condition that combines varying degrees of both hearing and visual impairment; people who are blind or deaf-blind (i.e., with severe vision impairments, or both severe vision and hearing impairments) cannot easily read, where only 10% of the blind children receive instruction in Braille. Researchers are focalized on navigation rather than environment disclosure; reading is one of the problems that related to information transmission. A portable reader position is discovered through either the identification of the closest reference tag surrounding it; wearable devices are distinctive from portable devices by allowing hands-free interaction, or at least minimizing the use of hands when using the device. This is achieved by devices that are actually worn on the body such as head-mounted devices, wristbands, vests, belts, shoes, etc.

Reading and travel are targets for wearable assistive devices that developed as task-specific solutions for these activities; they try to open new communication channels through hearing and touch. Devices are as diverse as the technology used and the location on the body. Fig. 1.1, as given in [32] overviews the body areas involved in wearable assistive devices as described by Velazquez [32] fingers, hands, wrist, abdomen, chest, feet, tongue, ears, etc. have been studied to transmit visual information to the blind.

Touch becomes the primary input for the blind people as receipt of non-audible physical information, where the 3D objects can rapidly and accurately identify by touch. There are three main groups of sensors organized by biological function defined by Velazquez in [32] the *Thermoreceptors*, responsible for thermal sensing, the *nociceptors*, responsible for pain sensing and the *mechanoreceptors*, sensitive to mechanical stimulus and skin deformation. Most of the assistive devices for the blind that exploit touch as the

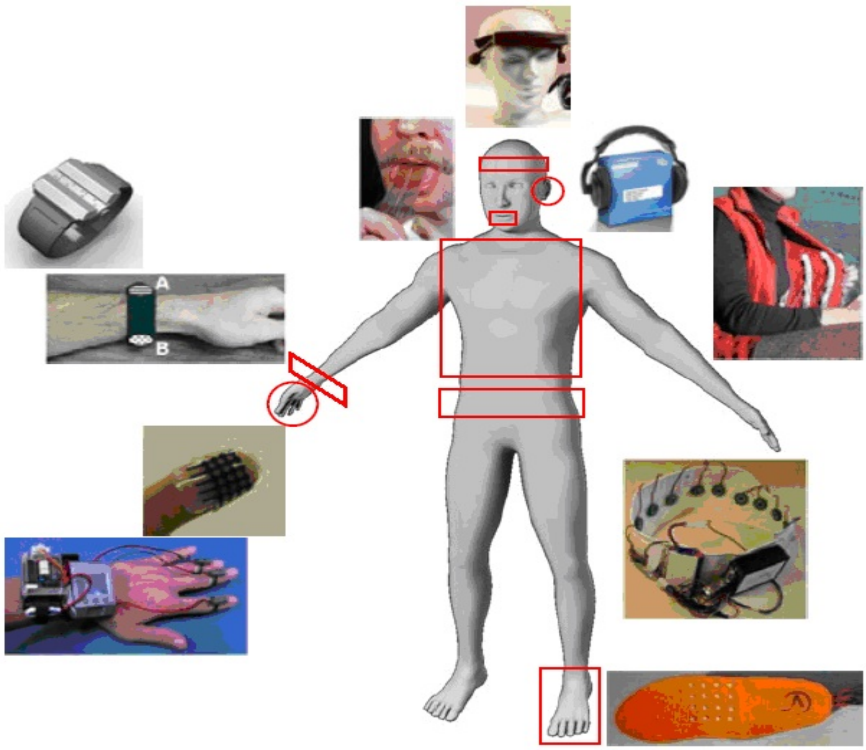

Fig. 1. Overview of wearable assistive devices for the VIP [32]

substitution sense are tactile displays for the fingertips and palms. Typical tactile displays involve arrays of vibrators or upward/downward moveable pins as skin indentation mechanisms.

Communication support technology and position identification technology are essential to support Deaf-Blind people. As communication interfaces, the Japanese proposed wearable Finger-Braille interfaces which are hands-free and can communicate with others in real-time. As positioning technology, they designed the ubiquitous environment for barrier-free applications which consists of network cameras, wireless LAN and floor-embedded RFID tags [33]. Finger-Braille is a method of tapping Deaf-Blind person's fingers to transmit verbal information, which are assigned to the digits of Braille. This method enables Deaf-Blind people to obtain information as if they are listening in real-time. The Japanese Finger-Braille interface is a wearable assistive device to communicate information to the deaf-blind that based on Japanese script, Kanji (the Chinese ideographic script), Hiragana and Katakana (syllabic script) are the three kinds of Japanese writing symbols used (The Association for Overseas Technical Scholarship, 1975) [34]. In this system, the fingers are regarded as Braille dots: 6 fingers, 3 at each hand, are enough to code any 6-dot Braille character. Some examples of translation given in [32] are shown in Fig. 1.

Glove-style interfaces seem to be the most suitable design for the Finger-Braille interface because they are easy to wear, where the first glove-based systems were designed in the 1970s, and since then, a number of different designs have been proposed. However, they cover the palm or the fingertip that has the highest tactile sensitivity.

Authors in [36] compared between two different wearable tactile interfaces, a back array and a waist belt with experimental trials, where the data were analyzed using a three-way repeated- measures ANOVA with tactile interface, screen orientation and visual display. There results suggest that the belt is a better choice for wearable tactile direction indication than the back array, however, their experiments did not seek to tease out which particular features of these two established approaches led to the observed differences.

5 Games for Visually Impaired People

Virtual reality and gaming technology have the potential to address clinical challenges for a range of disabilities. Virtual reality-based games provide the ability to assess and augment cognitive and motor rehabilitation under a range of stimulus conditions that are not easily controllable and quantifiable in the real world. People who cannot use the ordinary graphical interface, because they are totally blind or because they have a severe visual impairment, do not have access or have very restricted access to this important part of the youth culture. Research and development in the field of information technology and the disabled has focused on education rather than leisure [9, 12].

Indeed the mainstream commercial market for computer games and other multimedia products have shown a rather impressive development in the last years. For instance in 2002, costs for the development of games could vary between 300,000 Euros for a game on wearable device, to 30 millions for the biggest productions [12].

Visual impairment prevents player from using standard output devices. So the main problem of visually impaired player is to acquire the game information. Two modalities can be used to replace visual modality: sound modality or tactile modality. Audio computer games are games whose user interface is presented by using audio effects, while in tactile computer games user interface is based on a set of specialized touch-sensitive panels. Communities of the visually impaired tend to favor audio computer games, because there is a number of their members particularly those who were not born blind, but have acquired their blindness later in life, who are not familiar with tactile interfaces. The accessibility of multimedia games to the visually impaired does not rest solely on their ability to be presented in audio or tactile formats, but the language of the game is important as well [11].

5.1 Audio Games/Sonification

Recent progress in computer audio technologies has enhanced the importance of sound in interactive multimedia. The new possibilities to use sound in interactive media are very welcome to computer users that have difficulties in using graphical displays. Today, it is possible to create sound-based interactive entertainment, such as computer games [13, 10] designing of computer games that work for visually impaired children is a Challenge.

Sonification and visualization by sound, has been studied widely for decades and it has also been applied in software for blind people. The aim is to display, for example, graphics, line graphs or even pictures using non-speech sound [64]. By altering the various attributes of sound, for example pitch, volume and waveform, the sound is changed according to its visual counterpart. In the Sound-View application a colored surface could be explored with a pointing device. The idea was that the characteristics of colors, hue, saturation and brightness were mapped into sounds [15, 16, 17].

In 10 years, over 400 audio games have been developed, which is very small as compared to video games. Researchers could have an important role to play in that expansion process, by contributing to develop innovative features like a more pleasant audio rendering, by projecting audio games in a futuristic point of view by using uncommon technology like GPS for instance and by participate in the elaboration of games which can interest both visually and visually impaired community [12].

Current audio games can be studied with three dependency factors (1) dependency on verbal information, (2) dependency on interaction mechanisms based on timing and (3) dependency on the interaction mechanisms of exploration [12].

Action games directly refer to games coming from and inspired by arcade games and require a good dexterity of the player. One example of such games is "Tampokme" [58] is such an accessible audio game. In this game timing is essential. The player has to identify various kinds of audio signals and react accordingly and in fixed time. Adventure games offer players to take part in a quest. This type of game combines three essential features: an interesting scenario, the exploration of new worlds and activities of riddle solving. Example of such games is "Super Egg Hunt" [59] focuses on the move of the avatar on a grid, where the players must locate objects only from audio feedback. A quite clever use of stereo, volume and pitch of the sounds allows an easy and pleasant handling.

There are a few strategy audio games but the manipulation of maps is rather difficult without the visual. The game "simcarriere" [60] ignores the map aspect and focuses on the simulation/management side. The player has to manage a lawyer's office by buying consumable, hiring personal, and choosing the kind of cases to defend. Puzzle audio games are similar to video puzzle games in principle. "K-Chess advance" [61] is an adaptation of the Chess game, but focusing on audio. One can find a good number of audio games. The Swedish Library of Talking Books and Braille (TPB) has published web-based games dedicated to young children with visual impairment. On the other end, Terraformers is the result of three years of practical research in developing a real-time 3D graphic game accessible for blind and low vision gamers as well as full sighted gamers. A quite comprehensive list of audio games can be found in [9].

5.2 Tactile Games

Tactile games are games, where the inputs and/or the outputs are done by tactile boards or by Braille displays, in combination with usually audio feedback. Then during the TiM project [18], funded by the European Commission, several tactile games were developed [9, 12]. One was an accessible version of Reader rabbit's Toddler, where the children can feel tactile buttons on the tactile board, and then drive the game from this board.

Another game developed within the TiM project was FindIt, which was a very simple audio/tactile discovery and matching game. From this game game generator was developed which is currently being evaluated with practitioners working with visually impaired children. The generator allows educators and teachers who work with visually impaired children to design their own scenarios and to associate them with tactile sheets (that they design themselves manually) [9, 12].

6 Web-Based Information System for Blind and Visually Impaired

In this section we introduce Web-based information system accessibility,Web-based city maps support visually impaired people and Email accessibility support visually impaired people.

6.1 Web-Based Information System Accessibility

For visual impaired people, the application of the web content accessibility often might not even make a significant difference in terms of efficiency, errors or satisfaction in website usage. This section presents the development of guidelines to construct an enhanced text user interface as an alternative to the graphical user interface for visual impaired people. And one of the important current major problems for visual impaired people is the provision of adequate access to the WWW. Specialist browsers are beginning to emerge to provide a degree of access, along with guidelines for page design and proxy servers to assist in reorganizing a page to simplify spoken presentation. A further problem in the provision of access to the WWW is the emerging use of 3D images. The method of providing these 3D images for visual impaired people is still in an early stage of development. It is the purpose of this subsection is to identify potential solutions to the problem of access for visual impaired people, and to initiate a dialogue within the WWW developer community about this issue, before the methods of 3D presentation of images become unalterable.

Drishti [53] which is an integrated navigation system for visual impaired people uses the Global Positioning System (GPS) and Geographical Information System (GIS) technologies. It is designed to be used within the university premises and contains a GIS dataset of the university. This contains geographically referenced information for both static and dynamic environments and is referred to as a spatial database. The spatial database is accessible through a wireless network to a wearable device that is carried by the visual impaired people. A differential GPS receiver in the wearable device determines the localization of the user. Drishti is an assistive device which is operable in dynamically changing environments and can optimize routes for navigation when there is an unforeseen obstacle in the path. Like SESAMONET, Drishti gives assistance to the user by means of speech. Drishti may be considered as the first reliable assistive technology system which can help the navigation of visual impaired people in dynamically changing environments. However, there are two limitations with this system. First, the prototype weighs eight pounds. Second, the degradation of the RF signals inside buildings degrades the accuracy of the GPS localization.

Tee et al.[52] proposed a wireless assistive system using a combination of GPS, dead reckoning module and wireless sensor network for improved localization indoors and outdoors. The system is also designed to be light in weight. An important part of the system is the web-based system where system administrator can monitor and give assistance when required. The overview of their proposed system is depicted in Fig. 2. The proposed system consists of three components: SmartGuide hardware devices, mesh wireless sensor network and intelligent assistive navigation management system with the web-based system administrator monitoring system. The web based system enables r the system administrator to access and manage the system remotely with ease. The wireless sensor network is designed to be very low-power and fault tolerant by using a mesh network topology. Where the wireless sensor network has minimal delay in data relaying even with walls and obstacles, thus it is concluded the system would work reliably in indoor environments.

Dougles et al. [37] examined behaviors of 10 visually impaired adults carrying out a copytyping task, the adults with visual impairments had inefficient working habits; such as poor touch typing, rare use of short cut keys, lack of adjustment of equipment, furniture and copy material. Authors in [37] recommended more proactive and creative strategies for improving skills and work techniques and adjusting positions of equipment and furniture.

Dobransky et al. [38] presented technical accessibility problems as one of the extra barriers that people with a visual impaired people need to tackle. On other study by Hackett et al. [39], studied about usability of access for web site accessibility; six visually impaired computer users (two men and

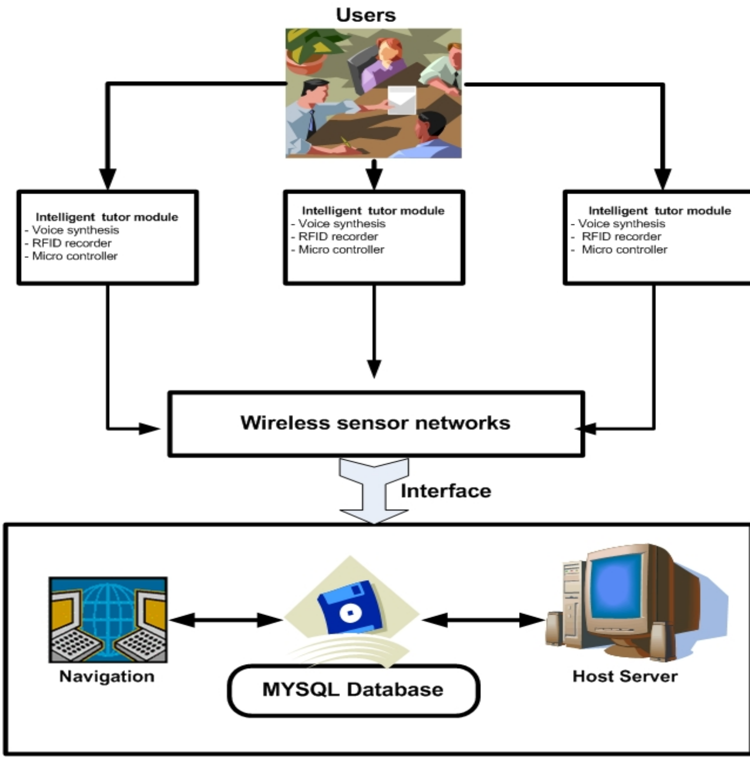

Fig. 2. Wireless system architecture

four women, aged 40 and older) were examined. In their study, six think-aloud assessments were conducted to compare access with the standard web display, with the goal of improving the design of access by identifying usability issues. The results showed that the visual impaired people were more satisfied with transformed web site. Also, Baye et al. [40] found that especially navigation and screen reading posed problems for blind internet users. Another study related to access and use of web by visually impaired students recommends web-site designers to be sensitive to the needs of visually-impaired users when preparing their information sites.

In early user interfaces a person interacting with a computer used a plug board or hard wired commands and saw the output on a pen recorder or electro-mechanical counter. This has rapidly developed into the popular personal computer interface seen today, i.e. a multimedia capability within a Windows, Icon, Mouse and Pointer environment. There is an ever increasing sophistication in the visual processing available at the user interface. The increasing visual sophistication of the human computer interface has undoubtedly improved ease of use. However, it has also reduced access for people with visual disabilities. Sophisticated methods now need to be employed to enable modern Windows, Icon, Mouse and Pointer interfaces to be used by visual impaired people. Most WWW documents are still written to be intelligible without the pictures. However, this is principally to cater for people with low performance computers or slow network links, rather than to provide alternative access for visual impaired people. We should therefore expect the situation for visual impaired people to worsen as the processing power and networking speed of personal computers grows.

The graphical user interface is the most widespread user frontend for applications today and the dominant user interface for websites on the internet. But graphical elements like windows and buttons are designed for sighted users; visual impaired people can neither perceive nor use them. To compensate for this disadvantage, several countries have passed laws to enforce accessibility of websites for handicapped users. Therefore, there is a discrimination against people with disabilities in all aspects of daily life, including education, work and access to public buildings. Some governments like Swiss act have required the government to provide access to all internet services for people with disabilities. Most approaches of developing a new user interface for visual impaired people pursue promising ideas, but lack quantitative empirical evaluation of the benefits for the visual impaired people. Stefan et al. [41] provided a direct quantitative comparison between two interface types.

In order to successfully use navigation, users first have to form a mental model of the underlying navigation space. In order to form a mental model, users have to make sense of the grouping and labeling of navigation items. This sense-making is based on cognitive processes coupled to sensory input. The sensory input leading to mental model formation is completely different for sighted and for visual impaired people: For sighted users, visual grouping and non-audible attributes (such as text size, color and formatting) yield a great deal of insight into the intended grouping of navigation items and hence communicate the intended structure of the navigation space. visual impaired people have to form their mental model of the navigation space based solely on the linear representation of navigation items and audible cues added to visually represented content.

Some qualitative insights and examples from exploratory studies that explains visual impaired people problems with a GUI:

- visual impaired people cannot guess relationships between primary and secondary navigation items if they are expressed visually,
- visual impaired people often only learn by chance which navigation options are recurrent on every page,
- it takes visual impaired people a lot of time to explore navigation options: Whereas trial and error is a valid navigation strategy for sighted users, we never observed blind users applying this strategy.

Thus, theories of navigation and qualitative insights from our exploratory studies demonstrate the necessity of a user interface that is enhanced regarding navigation through and interpretation of the linear representation of content, using user interface elements especially designed for the visual impaired people. The GUI has been introduced to make use of human perceptual abilities in order to reduce demands on working memory: Instead of learning hundreds of commands by heart, users could see all available commands for a selected object and reserve their cognitive resources mainly for decision making. The only reason sighted users can instantly use a computer program or website without training is their ability to see data objects represented on the screen together with the corresponding commands.

Stefan et al.[41] used a text-only interface in order to free visual impaired people from having to listen to additive clutter from visual impaired people interface elements, and impose a structure consisting of additive cues. The most serious limitation of arose from time constraints: Welcoming users to the usability lab, letting them get acquainted with the test setting and recording task execution of two tasks already took well over an hour.

6.2 Web-Based City Maps Support Visually Impaired People

Mental mapping of spaces and of the possible paths for navigating these spaces is essential for the development of efficient orientation and mobility skills. Most of the information required for this mental mapping is gathered through the visual channel. Visually impaired people lack this information, and consequently they are required to use compensatory sensorial channels and alternative exploration methods. Although digital maps become more and more popular, they still belong to those elements of the web which are not accessible to all user groups. So far, visually impaired and especially blind people do not get the chance to fully discover web-based city maps. One way to make web-based maps accessible for people with visual impairments is to describe the map in words. The goal is to develop a semantic description of the urban space that can be generated automatically so that worldwide deployment is possible [54]. Web-based maps support virtual and live discovery of cities, provide spatial information and improve orientation. Web-based city maps can be accessed either from home with a PC or on tour thanks to mobile devices, which may also be connected to GPS. However, this is not the case for blind and visually impaired people. To properly access and view digital maps is often challenging for this user group. Therefore, a methodology based on geographic information technologies is developed to automatically generate a textual spatial description of the map and a user specified interface respecting the requirements of users with visual impairment.

The work in [42] is based on the assumption that the supply of appropriate spatial information through compensatory sensorial channels, as an alternative to the visually impaired people channel, may help to enhance visually impaired people's ability to explore unknown environments [43] and to navigate in real environments. The area of touch-based human-computer interaction has grown rapidly over the last few years. A range of new applications has become possible now that touch can be used as an interaction technique. Most research in this area has been concentrated on the use of force feedback devices for the simulation of contact forces when interacting with simulated objects.

Research on orientation and mobility in known and unknown spaces visually impaired people indicates that support for the acquisition of spatial mapping and orientation skills should be supplied at two main levels: perceptual and conceptual. At the perceptual level, visual information shortage is compensated by other senses, e.g., tactile or auditory information. Tactile and touch information appear to be a main resource for supporting appropriate spatial performance for visually impaired people using a new concept *active touch*. Researches continued this line of research, active touch, focusing on the relationship between vision and touch information for visually impaired people in the context of philosophy and esthetics. Active touch can be described as a concomitant excitation of receptors in the joint and tendons along with new and changing patterns in the skin. Moreover, when the hand is feeling an object, the movement or angle of each joint from the first phalanx of each finger up to the shoulder and the backbone makes its contribution. Touch information is commonly supplied by the hands' palm and fingers for fine recognition of object form, texture, and location, by using low-resolution scanning of the immediate surroundings, and by the feet regarding surface information. The auditory channel supplies complementary information about events, the presence of other object such as machines or animals in the environment, or estimates of distances within a space. The olfactory channel supplies additional information about particular contexts or about people.

At the conceptual level, the focus is on supporting the development of appropriate strategies for an efficient mapping of the space and the generation of navigation paths. For instance, Jacobson [44] described the indoor environment familiarization process by visually impaired people as one that starts with the use of a perimeter-recognition-tactic-walking along the room's walls and exploring objects attached to the walls, followed by a grid-scanning-tactic-aiming to explore the room's interior. Research indicates that people use two main spatial strategies: route and map strategies. Route strategy is based on linear recognition of spatial features, while map strategy is holistic and encompasses multiple perspectives of the target space. Fletcher [45] showed that visual impaired people use mainly route strategy when recognizing and navigating new spaces.For a long period of time the information-technology devices that provided the visually impaired people with information before her/his arrival to an environment were mainly verbal descriptions, tactile maps and physical models. Today, advanced computer technology offers new possibilities for supporting rehabilitation and learning environments for people with disabilities such as visually impaired people. Over the past 30 years, visually impaired people have used computers supported by assistive technology such as audio outputs. The Optacon was one of the first devices to employ a matrix of pins for tactile-vision substitution and was the first device of this kind to be developed as a commercial product [46]. The input to the device is a 6x24 array of photosensitive cells, which detects patterns of light and dark as material is moved underneath. The display part of the device is a 6x24 array of pins on which the user places their fingertip. The output of the camera is represented by vibrating pins on the tactile display. Audio assistive technology includes text-to-speech software and print-to-speech reading machines (e.g., Kurzweil's Reading Machine invented in 1976). The exploration and learning of a new environment by visually impaired people is a long process, and requires the use of special information-technology aids. There are two types of aids: passive and active. Passive aids provide the user with information before his/her arrival to the environment, for instance [47]. Active aids provide the user with information in situ, for instance [48]. Research results on passive and active aids indicate a number of limitations that include erroneous distance estimation, underestimation of component sizes, low information density, or symbolic representation misunderstanding. Basically, Virtual reality has been a popular paradigm in simulation- based training, in the gaming and entertainment industries. It has also been used for rehabilitation and learning environments for people with sensory, physical, mental, and learning disabilities [49, 50]. Recent technological advances, particularly in touch interface technology, enable visually impaired people to expand their knowledge by using an artificially made reality built on touch and audio feedback. Research on the implementation of touch technologies within VEs has reported on its potential for supporting the development of cognitive models of navigation and spatial knowledge with visually impaired people [51]. The exploration process by visually impaired people is collected mainly using the touch and audio channels.

6.3 Email Accessibility Support Visually Impaired People

Email is one of many desktop applications that have become increasingly portable and web-based. However, web-based applications can introduce many usability problems, and technology like Flash and AJAX can create problems for blind users [56]. The blind users are more likely to avoid something when they know that it will cause them accessibility problems, such as the problems often presented by dynamic web content. The 70-75% unemployment rate of individuals who are blind in the US makes it essential that they identify any email usability problems that could negatively impact blind users in the workplace [57].

Brian et al. [55] discussed results of usability evaluations of desktop and web-based email applications used by those who are blind. Email is an important tool for workplace communication, but computer software and websites can present accessibility and usability barriers to blind users who use screen readers to access computers and websites.

To identify usability problems that blind users have with email, 15 blind users tested seven commonly used email applications. Each user tested two applications, so each application was tested by three to five users. From the results, we identify several ways to improve email applications so that blind people can use them more easily. The findings of this study should also assist employers as they make decisions about the types of email applications that they will use within their organizations. This exploratory research can serve as a focus for more extensive studies in the future.

7 Conclusion and Challenges

This chapter discussed and investigate the effects of the virtual reality technology on disabled people, especially blind and visually impaired people in order to enhance their computer skills and prepare them to make use of recent technology in their daily life. As well as, they need to advance their information technology skills beyond the basic computer training and skills. In addition, we explained what best tools and practices in information technology to support disabled people such as deaf-blind and visual impaired people in their activities such as mobility systems, computer games, accessibility of e-learning, web-based information system, and wearable finger-braille interface for navigation of deaf-blind. Moreover, we showed how physical disabled people can benefits from the innovative virtual reality techniques and discuss some representative examples to illustrate how virtual reality technology can be utilized to address the information technology problem of blind and visual impaired people.

The main challenge on VR technique is to enhance accuracy, reduce computational cost, and to improve the proposed technique toward tracking applications. There are many challenge points must covered by any VR systems as, supports accurate registration in any arbitrary unprepared environment, indoors or outdoors. Allowing VR systems to go anywhere also requires portable and wearable systems that are comfortable and unobtrusive. A VR system should track everything: all other body parts and all objects and people in the environment. Systems that acquire real-time depth information of the surrounding environment, through vision-based and scanning light approaches, represent progress in this direction. New visualization algorithms are needed to handle density, occlusion, and general situational awareness issues. Many concepts and prototypes of VR applications have been built but what is lacking is experimental validation and demonstration of quantified performance improvements in a VR application. Such evidence is required to justify the expense and effort of adopting this new technology. Basic visual conflicts and optical illusions caused by combining real and virtual require more study. Experimental results must guide and validate the interfaces and visualization approaches developed for VR systems. Although many VR applications only need simple graphics such as wireframe outlines and text labels, the ultimate goal is to render the virtual objects to be indistinguishable from the real.

This must be done in real time, without the manual intervention of artists or programmers. Some steps have been taken in this direction, although typically not in real time. Since removing real objects from the environment is a critical capability, developments of such Mediated Reality approaches are needed. Technical issues are not the only barrier to the acceptance of VR applications. Users must find the technology socially acceptable as well. The tracking required for information display can also be used for monitoring and recording.

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