ASSISTIVE I.T. FOR VISUALLY IMPAIRED PEOPLE

Oana Bălan[1]
Alin Moldoveanu
Florica Moldoveanu
Anca Morar
Victor Asavei

ABSTRACT

According to an international survey performed by the World Health Organization, it was estimated that the number of visually impaired people in the year 2002 rose to about 161 million (2.6% of the world's population). Therefore, a large number of people are suffering from a visual handicap which impedes them from normally accomplishing their daily activities. As a result, there is need for an assistive device based on an alternative modality, that can complement or replace sight by another sense -auditory, haptic (tactile or kinesthetic) [13], or a combination of both- and that can offer a means to deal with blindness.

Rapid progress is ongoing in various fields of medicine, as advances in computer technology are enhancing extended development and evolution in simulation, visualization and virtual reality systems. As a result, a convenient approach is the use of augmented reality for the development of assistive devices for visually-handicapped people.

This paper presents the current state of research in the field of virtual reality and six assistive devices for visually-impaired people, the technology engaged to provide effective and reliable benefits and some of the most interesting and innovative applications in the area of rehabilitation techniques based on another senses.

***Keywords*—sensory substitution, assistive IT, virtual reality, augmented reality**

1. INTRODUCTION

According to an international survey performed by the World Health Organization, it was estimated that the number of visually impaired people in the year 2002 rose to about 161 million (2.6% of the world's population), of whom 124 million had sight deficiencies, while 37 million were blind (legal or total blindness) [13]. Therefore, a large number of persons are suffering from a visual handicap which impedes them from accomplishing their daily activities. As a result, there is need for an assistive device based on an alternative modality, that can complement or replace sight by another sense -auditory, haptic (tactile or kinesthetic) [13], or a combination of both- and that can offer a means to deal with blindness.

Vision substitution techniques have been intensively studied over the last century. Use of combined modalities to convey visual information (haptic, auditory and

[1] Facultatea De Automatică Şi Calculatoare, Universitatea Politehnica Din Bucureşti, oanab_2005@yahoo.com

auditory/haptic) is relatively recent, but has an ascending trend, due to the intense attention devoted to developing assistive technologies [21], [22] and because of the evident benefits of associating all possible communication and interaction channels and.

The foundations of sensory substitution have been validated for the last 30 years [23], but the existing devices seem to be inefficient in what concerns actual problems and situations that appear in the day-to-day activities of visually handicapped subjects. Thirty years ago, the American neuroscientist Paul Bach-y-Rita [6] made an experiment that put a solid basis on the field of sensory substitution. Therefore, he transferred the image captured by a video camera onto a 20 by 20 matrix of vibrotactile pins, placed on the back of a dentist chair. Using this device, the blind subjects sitting on the chair could recognize and identify simple visual patterns.

A reasonable visual prosthesis should be portable, has to take into account the end user's needs and give good results in a short time scale [6].

Navigation aid devices, generally known as Electronic Travel Aids, improve the quality of life of sight-impaired people by helping them to perceive the surrounding environment. Electronic Travel Aids are classified as follows: obstacle detectors based on ultrasonic and laser beams emission into the environment in order to calculate the distance between the subject and the detected object, navigation systems with the purpose of acknowledging information about the setting and position of the subject in local or global coordinate system of the scenery and environmental sensors.

2. ASSISTIVE SYSTEMS FOR PREDEFINED ENVIRONMENTS

The Drishi navigation system [1] maps the information from the environment and answers the requested queries from the user through a speech-recognizing model. The mapping information is stored in a database that can be dynamically updated as the user moves through the environment and encounters other objects. The devices also provide GPS localization for outdoor displacement.

A similar device is SmartGuide [19], whose initial purpose was assisting and surveying the user's travel in a university campus. It also guides the user through speech to the desired location and provides the available pathways that he can follow.

Guentert [10] proposed an audio software application for iPhone that can help blind people travel safely by train. This system presents the disadvantage of not providing the user's position and not monitoring his path continuously.

Hub et al [2] proposed a system based on a stereoscopic perspective of the reality for monitoring the distance to the surrounding objects. The detected objects are being compared with a 3D model. This approach is not efficient, because of the use of large amount of data and the impossibility of modeling complex or dynamic environments.

Despite their interactivity and feasibility, the assistive devices for predefined environments have limitations concerning their usability only in known environments and pre-designed settings.

3. VISION-SUBSTITUTION TRAVEL AID SYSTEMS FOR UNKNOWN ENVIROMENTS

Virtual Reality Simulator For Visually Impaired People

Main Idea

Virtual Reality Simulator for Visually Impaired People [18] is a system developed in order to create an auditory representation of the environment for people who suffer from sight deficiencies. The main idea of this project concerns the calculation of the distance between the subject and the nearby objects that surround him, and the conversion of this distance into sound, thus rendering the entire virtual environment through hearing. The concept that lies behind the transcription of the visual representation into auditory information is the sonification process. The visual cortex of a blind person can become responsive to sound, hence an assistive device such as Virtual Reality Simulator may enhance the neural plasticity of the brain, providing synthetic vision with truly auditory sensations.

Results

The Virtual Reality Simulator is comprised of a set of small modules (the 3D Simulator, the Tracking System and the Sound System) (Fig. 1), working independently or simultaneously and performing various tasks. The components of the system are: the 3D distance sensor (a pair of glasses), a hardware sound device and a pair of headphones. The 3D Simulator performs the rendering of the scene, distance calculations, depth map analysis that provides the information for the Sound System and device-user communication. The 3D Simulator generates a depth map from the real scene and provides visual information for the user interface about the virtual environment of the simulator. The 3D engine is implemented in C++ and OpenGL and uses the Fox Toolkit Library. The simulator manages two groups of scenes- the background group that gives visual feedback, used as a reference system, and the main group of scenes, that are used for designing the depth map the user is interacting with. The simulator loads the scenes from a 3D mesh with 3000 polygons. The depth map, calculated from the 3D mesh, is a 2D representation that encodes, for each pixel, the distance from the camera. For example, lighter values stand for close distances, while darker values indicate farther distances. The depth calculation algorithms have been written in GLSL shading language, enabling the addition of other algorithms, without reprogramming the simulator [18].

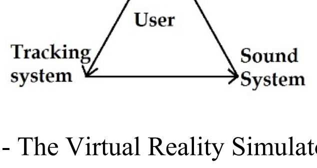

Fig. 1- The Virtual Reality Simulator [18]

The sound renderer module converts the depth map into an auditory one, by spatializing the sound according to its virtual location. Each position is characterized by a specific sound. The 3D perception and accuracy detection is ensured by applying the HRTF (Head Related Transfer Function) - a characteristic of how the sound is perceived from one position or a specific angle in space. The sonification module consists of a series of techniques that select, sort and transfer the sounds into a sequence that will be conveyed to the user through a pair of headphones. The virtualization and mixing of sounds are performed in real-time. The sonification strategies employed are: testing different available HRTF databases, using different sample sizes for the HRTF impulses, randomizing the sounds' order or presenting them linearly, using various processing sounds for the convolution with the HRTFs.

There has been conducted an experiment in which the subjects compare the performance of the device when they are presented an object or an obstacle (column or wall), to enable the detection and representation of narrow or wide objects. Also, they were given specific navigation tasks in a training setup, where the user had to get accustomed to the environment, identify objects present in the scene and their location, recognize the scene, complete the itinerary in a given time and correct previously made mistakes. The subjects perform these tasks in training environments (virtual or real), moving around fake furniture, walls or columns, in order to learn and identify the whole background. In this kind of training sessions, the measured indicators are: completion time, correct orientation in space, accuracy of localization and position detection, trajectories followed during the session. The newest prototype integrates the 3D distance sensor in a pair of glasses and incorporates an infrared Time of Flight 3D camera for the improvement of mobility simulations.

The Virtual Reality Simulator proved to be helpful for vision disabled people in different research experiments performed indoors and outdoors, in virtual and real life situations.

Limitations

The main limitations that have to be overcome are: the adaptability of the simulator, which has to be designed in order to allow multiple setup configurations, the complexity of the scenes, tracker accuracy (that has to be configurable for a larger workspace). A possible solution stands for calibration and distortion software improvement.

Expected Evolution

As future work, the tracking calibration will be revised for a more accurate detection. Also, the scene file types will vary with more 3D common formats, while the incorporation of a physics simulation engine will create a more realistic environment, as now it is mostly inactive. Different sound encodings for various object categories are suitable for improvement and enhancement. In addition to this, using neural networks to obtain patterns for sound conversion is also an efficient and reliable method for the technological advancement of the system.

The Vibe

Main Idea

The Vibe [13] [6] is an assistive system that converts video streams coming from a camera into auditory information, rendered to the user through a pair of headphones. This device makes a correlation between the coordinates of the image into the visual space and the audio representation of sound. For instance, it encodes top/bottom positions with high/low tone, and left/right locations with left panning/right panning.

Results

The Vibe maps the image extracted from the camera into a set of receptive fields, distributed uniformly in the picture. A receptive field is a set of pixels, grouped in a limited area. To each receptive field it corresponds a particular sound, characterized by a frequency value and a panning, determined by the vertical and horizontal location of the receptive field's center.

An experimental procedure took place in a U-shaped car park maze. 20 blindfolded subjects equipped with The Vibe, had to complete the track 3 times. The experiment had four sessions (three for training and one for test), separated by at least 24 hours. The results of the experiment were evaluated based on the time of completion (Run Time) and the number of mistakes- number of times the subject crossed the bound of the track. (Number of Contacts). Using various statistical calculations (Friedman non-parametric test of variance, Student t-test), the conclusions drawn revealed two main advantages over other procedures: significant results after a short learning time even under noisy conditions and decrease in the number of contacts after completing the training sessions, under normal and reversed conditions.

The experiment is practically efficient because it has an impact on the subject's mobility, thus being adequate for the development of the visual assistive device in what concerns the user's necessities.

Limitations

Pattern recognition depends on the resolution of the device, and a small number of points available in the visual field are not usually enough for a good detection of the objects in space. The actual devices are not able to give a realistic insight into the practical situations of using a sensory substitution system on a regular basis in daily life.

Expected Evolution

Recent developments and advances in the understanding of signal processing in the visual system offered new pathways for the optimization of visual aids in the case of unsighted subjects. These methods should be applied to evaluate the qualitative and quantitative performances of the assistive devices when used in a realistic environment, so that they can give good results in a short time scale.

See Color

Main Idea

The SeeColor project [13] [23] is a device designed to represent real-time images using the auditory channel. The main idea of the system is to help blind subjects to reconstruct mentally the frontal scenes of the environment. Colored objects of the reality are depicted using three-dimensional sound sources that indicate position, localization and cardinality, enabling vision impaired people to navigate in an unknown environment.

The mental simulation model is basically formed starting from audio. The researchers tried to replace the visual sense, which is parallel, with a parallel representation of the audio signals in time. The characteristics of the setting are mapped into multiple signal features, encoded by sound duration or musical instruments sounds.

Results

The purpose of the SeeColor prototype is to transform typical colors (green, red, yellow, in the case of a crosswalk), into musical instruments sounds. For example, the sounds rendered in the 3-dimensional virtual environment that correspond to each colored pixel location are flute, for green pixels, and piano, for yellow ones. Object depth is encoded by the length of the signal and has four possible durations that correspond to four depth values. In what concerns image processing, to build a more consistent scene of the environment, the goal is to decrease the number of insignificant colors and retain only the important ones.

The experiments conducted in time proved the close connection between colors and musical instruments sounds. It is obviously easier and more accessible to link visual information to specific instrumental sounds. An experiment carried on with the aid of 15 participants demonstrated that sounds can help locate and associate objects of different or similar colors.

The prototype has also been tested for mobility assistance, where a subject had to follow a red painted line on the ground. It was proven that the combination of real-time modulation and the distance information gave correct and precise information to facilitate subject displacement.

Limitations

This device is addressed to blind people who have seen before their visual impairment. The limitation of the SeeColor prototype lies in the unfeasibility of using this device to congenitally blind people, because they are unable to distinguish the colors and cannot have the sense of perspective transformations. However, they suffer from imagery limitations when scenes and images increase in complexity.

In addition, researchers should take into account the issue of reducing the size of the devices, so that they can be confortable to the user and acceptable to be worn in public. Nevertheless, lowering the cost of the system and using a sophisticated technology for both audio and video processing are compelling for developing an efficient and accurate visual-substitution system.

Expected Evolution

Future work concerns the extraction of basic color properties, consequently to reducing as much as possible the effects of light in the image. Work is underway to determine the salient regions of the image, thus attracting the attention of the user towards the most noticeable parts of the scene.

The Voice

Main Idea

The main idea of the system The vOICe [6] [13] [24] (the capital letters are the abbreviation of "Oh I See") is to create a sensory substitution assistive device based on image-to-sound renderings that uses basically the physical properties of the sound to represent the visual surrounding information. The vOICe is a very well-known prototype, whose principles led to the realization of other experiments and trials over the last years. The goal is to provide synthetic vision using a non-invasive prosthesis that exploits the capacity of adaptation of the brain in the complete absence or deterioration of a sense.

Results

The Voice maps a 64 X 64 gray level picture into different sound levels. Views are refreshed once per second, while each pixel has associated a sinusoidal tone, defined by the pixel's vertical and horizontal position in the 60 X 60 resolution map. The video-to-audio mapping has associated height (vertical position) with pitch (high frequencies at the top of a column and low frequencies at the bottom of a column) and brightness with amplitude (loudness) in a left-to-right scan of the frame.

The Voice technology consists of a head-mounted, non-invasive video camera that converts images into soundscapes and transmits them via headphones. The wearable device includes also a notebook PC and costs around 2500 dollars. The software for the device is available for free download. Peter Meijer, the researcher who developed The Voice system, is convinced that, by using the brain's adaptive capacity (brain plasticity), blind subjects can mentally reconstruct and translate the visual content of the environment in a fluent and continuous way, like natural perception, without any conscious effort at all [24].

Blue Edge Bulgaria developed a simplified, but portable version of The Voice, compatible with Nokia mobile phone cameras [24].

Limitations

Because the combination of amplitude and frequency for a sound, it requires extensive training to interpret the resulting signal for a given group of pixels in the current scene. In addition to this, the system does not provide depth information about the location of the object in space. The left-to-right perception is not continuous, as expected from the visual sense, which processes information at the same time from multiple directions.

Expected Evolution

For efficiency, to adjust the visual field, an accelerometer is required in order to provide a steady image, even with the movement of the head. Also, connecting an infrared sensor to adjust the camera position corresponding to the eye movements can provide a better reconstruction of the reality. In addition to this, future extensions include support for object recognition (reading large prints, headlines, street signs, labels), eye-tracking (augmented-reality glasses for totally blind subjects, localization, absolute position of an object, cardinality), location technology with GPS, binocular vision with a stereoscopic camera hardware for better depth and perception sensations, in order to detect objects and obstacles. The binocular paradigm uses the anaglyphic processing method, which combines two viewpoints through two different color filters, usually red for the left eye and cyan or green for the right eye. The Voice analyses the 3D image generated from the anaglyphic approach and creates a depth map that is translated into spatial sounds, according to the distance of the landmark.

For instance, Minoru (Japanese word that stands for “Reality”), world’s first 3D camera [25] can be successfully used in combination with The Voice, to create a stereoscopic anaglyphic processing of the reality that can be transferred to visually-handicapped subjects through auditory perceptions. Minoru is defined by depth image output, camera calibration, stereo and anaglyphic capture. Signal information extracted from Minoru 3D camera can be edited with Open CV, a computer vision library developed by Intel, designed for real-time image processing.

Nevertheless, a disadvantage of the binocular anaglyphic stereoscopic system is the fact that it is more difficult to distinguish between the foreground and the background scenes than in the case of stereo frames.

Kinect For The Blind

Main Idea

Kinect for the Blind [26] was designed to help blind people orient and localize position on the street (direction, distance, dimensions of obstacles). This device differs from the usual assistive aid for the visually impaired (for example, the white cane), in what concerns the fact that it can detect obstacles simultaneously, in all directions (up, down, left and right), while the white cane can track only one object once.

Results

This system works by using Kinect for Xbox 360 sensor, which can determine depth directly, not by composing it from stereo frames. It uses an infrared flash and receiver that measures per-pixel light delay. Kinect for the blind transforms the depth map resulting from the sensor through a set of heuristic filtering methods and scales it down to a belly-mounted 8 x 4 tactile matrix.

The tactile matrix makes the user “feel” the depth of an object in space through the pixels that receive voltage periodically. The rate of frequency of the voltage indicates the distance to a specific object. The more frequent it is, the closer is the object corresponding to that pixel. Tactile data is transferred via USB-to-UART FTDI Interface and controlled by ATmrga32 board.

Visual-Aid System	Sensory Substitution Encoding	Substitution modality	Addressability	Commercial device
VR. Simulator for Visually-Impaired People	Audio	Distance to objects is encoded by the amplitude of sound Depth image map is converted into an audio map by using the HRTF	Congenitally, early and late blind people	No
The Vibe	Audio	Top/bottom position-frequency of sound (low/high pitch) Left/right position-left/right panning	Congenitally, early and late blind people	No
See Color	Audio	The color of objects is encoded by musical instruments sounds Distance is encoded by the length of sound	Early and late blind people Not recommended to congenitally blind people	No
The Voice	Audio	Top/bottom position-frequency of sound (low/high pitch)	Congenitally, early and late blind people	Yes
Kinect for the blind	Haptic	Tactile matrix that enables users to perceive the depth of objects	Congenitally, early and late blind people	No
Real-Time Assistance Prototype	Audio	Distance is encoded by sound frequency (low/high pitch) 3D directional sound by using the Head Related Transfer Function	Congenitally, early and late blind people	No

Table 1- A comparative study between the main visual-aid systems available

Limitations and Expected Evolution

Kinect for the blind does not offer a very accurate perception of depth.

Because the pins are quite massive, they can be softened by covering them in a piece of napkin.

The Real-Time Assistance Prototype

Main Idea

The Real-Time Assistance Prototype [5], a device developed at the Research Center in Graphic Technology of the Universidad Politecnica de Valencia, tracks objects in the surrounding space by providing the user an acoustic signal of the path, as he navigates in the environment. The hardware device is comprised of a pair of stereo cameras that record information ranging from 32 degrees to the left to 32 degrees to the right and headphones for the transmission of the signal to the subject. The system can detect objects in a natural environment that are placed at a distance between 1 and 15 meters, covering a range of 64 degrees. The surrounding information is achieved using algorithms of segmentation and depth mapping analysis. The acoustical system involves the use of binaural sounds for a better localization in space. Binaural sounds are the result of the convolution process of a monaural sound with the sound localization cues- HRTF- Head Related Transfer Function- the transfer change in sound shape from the point where the sound is emitting to the location of the listener.

The acoustical system encodes objects' position in space based on object distance (inverse proportional to the sound frequency), object direction (a sound displacement from the direction of the object) and object speed, which is proportional to the pitch change intensity.

Results

Two experiments have been performed in order to analyze the performance of the Real-Time Assistance Prototype. In the first experiment, the four totally blind subjects were asked to stay unmoved and to identify the direction of the sound, whereas in the second experiment, they had to identify the location of the moving sound and to follow it. In the second experiment, four lengths of the object distance were tested- near (5 m), far (10 m), very far (12 m) and very, very far (15 m). The results showed that even if the traveler correctly identified the sound source, when following it, he lost it several times. The prototype provides good results for far objects detection and for moving objects, as a request from the blind people community that supported the idea of developing a system capable of recognizing when an object gets nearer. The Real-Time Assistance Prototype can reliably detect objects situated at a distance between 5 and 15 m.

Limitations and Expected Evolution

As a limitation, the system is unable to identify objects at the ground level, due to the stereo vision technology employed, which cannot process depth information for small objects. Also, the user is constrained to the visual area of 64 degrees (32 degrees to the left and 32 degrees to the right).

In order to develop a perfect system, several improvements need to be undergone: sensory device to detect near and far objects, a GPS System to enhance navigation and a Head Positioning System.

Haptic Devices

The haptic devices use as sensory substitution method the tactile and kinesthetic encoding and representation.

The haptic systems evolved considerably over the last decades. One of the first devices developed [11] was comprised of a video camera and an electronic equipment made of an array of 20x10 tactile receptors placed on the back of a chair. The user felt the impulses transmitted through the receptors and could detect the location of different objects or persons in space.

In [12], the disadvantage of using high voltage level for conveying the electric energy to the back chair's pins has been suppressed by employing an array of 7x7 pins on the user's tongue. It enabled the subject to identify primarily geometrical shapes: circles, squares or triangles.

Zeng et al [8] proposed a system based on a TOF (Time-of-Flight) camera, a portable Braille module with 30x2 resolution, a white cane that uses a Wii vibrating remote controller and an audio system. The user could either "inspect" (stay in a fixed position) or "monitor" (move into the environment). This system provides information about the position (relative distance), shape, width, height and type of object (obstacle at ground, middle or head level). This device is rather efficient, but presents the disadvantage of being quite uncomfortable and time-consuming for the user, who has to read on the Braille display the result of the analysis of the scene. The Braille display has a low resolution, thus offering little detailed information about the setting.

4. A COMPARATIVE STUDY BETWEEN THE DEVICES PRESENTED

All the 6 analyzed devices prove to be a good solution that addresses the problem of object detection and navigation in the surrounding environment for the visual-impaired people, as resulting from the experiments performed. The sensory substitution encoding techniques are either audio or haptic, while the substitution modalities employed range from the use of HRTF impulses, sound amplitude, frequency and musical instruments sounds for encoding distance, top/bottom position or color of objects. These systems are dedicated to congenitally, early or late blind people. Nevertheless, the only commercial device available on market is The vOICe, while the others are only experimental prototypes (Table 1).

5. CONCLUSIONS

Until now, many electronic devices that assure assistance to visually-impaired people have been developed, but actually few of them are used on a daily basis [4] (Table 1). The aim of sensory substitution systems is to restore to blind people the capacity to categorize and localize objects rapidly. Such a device can address one of the major problems faced by the visually handicapped people- assistance for their daily life, cardinality, autonomy, mobility and prevention of random situations (obstacles or dangers). There are many devices that help blind people's displacement (Electronic Travel Aids-ETA- and Electronic Orientation Aids-EOA). The other technologies present- Location Based Services, artificial vision, and obstacle detection sensors are dedicated to visually-handicapped subjects, but none of these assistive devices enables a blind person to recognize and localize nearby objects.

Neuroscience research has shown that the visual cortex (the area of the brain responsible with sight) can become responsive to sound [13]. On the other hand, it was proven the brain has the capacity to categorize object very fast [4]. A 2D model can be localized very quickly (12 ms), and a large number of visual forms (around 40kb) can be stored even on mobile devices (PDA, smartphones). Spikenet can be used to reconstruct 3D objects from a pinhole stereoscopic 60 degrees camera, where distances can be calculated with a precision of 20 cm at a distance of one meter [4].

Image/video processing involves thresholding operations, segmentation, and extraction of contours, elimination of noise and other simplification techniques (contrast enhancement, zooming, and magnification). To describe the semantic content of a scene, object recognition and video data interpretation are required. An advantage of this method is to embed complex algorithms with high

performance rates, even for portable devices [4].

Electronic devices can enhance the autonomy and mobility of blind users. It is important to focus on the skill of subjects to detect and determine the position of targets in the visual field, as for them, the most important aspect is to manage to navigate in unknown environments, to locate obstacles and to identify similar objects.

The modalities of substituting a sensory channel (haptic, auditory and auditory/haptic) are rather sequential, not involving multiple senses at the same time. To counteract the limitations of these methods, a clear benefit would be brought by exploiting all the parallel interaction channels.

Auditory encoding, even if it uses low-cost devices, must handle the issue of high information loss data when transferring visual to audio information.

In conclusion, sensory substitution aids have the advantage of being simple, practical, portable, removable, wearable, and offer a good alternative to implants and to surgical interventions.

In what concerns human-computer interaction, there is need to make these devices more ergonomic and easier to interact with. In terms of appearance, they have to be acceptable to be worn in public and relatively inexpensive for the vast blind population who cannot afford to buy costly equipment [4].

Assistive electronic devices can address one of the major problems faced by the visually handicapped people- assistance for their daily life, cardinality, autonomy, mobility and prevention of random situations (obstacles and dangers).

6. REFERENCES

1. Abdelsalam Helal, Steven Edwin Moore, Balaji Ramachandran, *"Drishti: An Integrated Navigation System for Visually Impaired and Disabled"*, Proceedings of the 5th International Symposium on Wearable Computers, pp. 149-156, 2001
2. Andreas Hub, Joachim Diepstraten, Thomas Ertl, *"Design and Development of an Indoor Navigation and Object Identification System for the Blind"*, Proceedings of the 6th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 147-152, 2004
3. Bronzino, J.D., *The Biomedical Engineering Handbook*, Second Edition, Volume I, Crc Press
4. Dramas F., Oriola B., Katz B., Thorpe S., Jouffrais C., *Designing an Assistive Device for the Blind Based on Object Localization and Augmented Auditory Reality*, ASSETS'08, October 13-15, 2008, Halifax, Nova Scotia, Canada
5. Dunai L., Fajarnes Peris G., Praderas V.S., Garcia Defez B., Lengua Lengua I., Real-Time Assistance Prototype- a new Navigation Aid for blind people, Research Center in Graphic Technology, Universidad Politecnica de Valencia, 2010 IEEE
6. Durette B., Louveton N., Alleysson D., Herault J., *Visuo-auditory sensory substitution for mobility assistance: testing TheVIBE*, Grenoble, France
7. Gorman P.J., Meier A.H., Krummel T., *Simulation And Virtual Reality In Surgical Education*, Arch Surg/Vol 134, Nov. 1999
8. Limin Zeng, Denise Prescher, Gerhard Weber, *"Exploration and Avoidance of Surrounding Obstacles for the Visually Impaired"*, Proceedings of the 14th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 111-118, 2012
9. Lippincott W., *Surgical Simulation and Virtual Reality: The Coming Revolution*, Annals of Surgery, Vol. 228, No. 5, 635-637, 1998
10. Markus Guentert, *"Improving Public Transit Accessibility for Blind Riders: A Train Station Navigation Assistant"*, Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 317-318, 2011
11. Paul Bach-Y-Rita, Carter C. Collins, Frank A. Saunders, Benjamin White, Lawrence Scadden, *"Vision Substitution by Tactile Image Projection"*, Nature, vol. 221, pp. 963-964, 1969
12. Paul Bach-y-Rita, Kurt A. Kaczmarek, Mitchell E. Tyler, Jorge Garcia-Lara, *"Form perception with a 49-point electrotactile stimulus array on the tounge: A technical note"*, Journal of Rehabilitation Research and Development, vol. 35(4), pp. 427-430, 1998
13. Pun T., Roth P., Bologna G., Moustakas K., Tzovaras D., *Image and Video Processing for Visually Handicapped People*, EURASIP Journal on Image and Video Processig, Volume 2007
14. Riva G., *Applications of Virtual Environments in Medicin*e, Methods Inf Med 5/2003, 2003
15. Schultheis M., Rizzo A., *The Application of Virtual Reality Technology and Rehabilitation*, Rehabilitation Psychology, 2001, Vol. 46, No. 3, 296-311, 2001
16. Stone R., McCloy R., *Virtual Reality in Surgery*, BMJ. 2001 October 20; 323(7318): 912–915, 2001
17. Szekely G., Satava R., *Virtual Reality in Medicine*, BMJ VOLUME 319, 1999
18. Torres-Gil, Casanova-Gonzalez M.A., Gonzalez-Mora O., *Applications of Virtual Reality for Visually Impaired People*, Universitad de La Laguna, WSeas Transactions on Computers, Issue 2, Volume 9, February 2010
19. Z.H. Tee, L.M. Ang, K.P. Seng, J.H. Kong, R. Lo, M.Y. Khor, *"SmartGuide System to Assist Visually Impaired People in a University Environment"*, Proceedings of the 3rd International Convention on Rehabilitation Engineering & Assistive Technology", 2009
20. Zajtchuk R., Satava R., *Medical Applications of Virtual Reality*, Communications of the ACM, September 1997/Vol. 40, No. 9

21. R. G. Lupu, F. Ungureanu, V. Siriteanu, “Eye Tracking Mouse for Human Computer Interaction”, The 4th IEEE International Conference on E-Health and Bioengineering - EHB 2013
22. R. G. Lupu, F. Ungureanu, “Mobile Embedded System for Human Computer Communication in Assistive Technology”, 2012 IEEE 8th International Conference on Intelligent Computer Communication and Processing, 2012
23. http://cvml.unige.ch/doku.php
24. http://www.seeingwithsound.com/
25. http://www.minoru3d.com/
26. http://www.zoneos.com/kinectfortheblind. htm
27. http://www.vrphobia.com/
28. http://medicalaugmentedreality.com/
29. http://www.columbia.edu/cu/21stC/issue-1.4/doctor.html
30. http://www.vrs.org.uk/