Proceedings of the 4th International Conference of Control, Dynamic Systems, and Robotics (CDSR'17)
Toronto, Canada – August 21 – 23, 2017
Paper No. 121
DOI: 10.11159/cdsr17.121

Portable Monitoring and Navigation Control System for Helping Visually Impaired People

Mohit Sain, Dan Necsulescu
University of Ottawa
161 Louis Pasteur, Ottawa, Canada
msain064@uottawa.ca; dan.necsulescu@uottawa.ca

Abstract **-** Visual Aids for the blind people is an important subject. Apparently visually impaired individuals get impeded by certain hurdles in everyday life. This work proposes an indoor navigation system for visually impaired people. In particular, the goal of this study is to develop a robust, independent and portable aid to assist a user to navigate familiar as well as unfamiliar areas. The algorithm uses the data from Microsoft Xbox Kinect 360 which makes a 3D map of the indoor areas and detects the depth of an obstacle/human. To ensure the accuracy, Kinect tool is enabled with a colour camera to capture real-time details of surroundings which are then processed accordingly. Besides, the developed aid makes the user aware of environment changes through a Bluetooth enabled headphones used as audio output device. The trials were conducted on six blindfolded volunteers who successfully navigated across various locations in the university campus such as classrooms, hallways, and stairs. Moreover, the user could also track a particular person through output generated from processed images. Hence, the work suggests a significant improvement for existing visual aids which may be very helpful in customization as well as the adaptability of these devices.

Keywords**:** Indoor Navigation, Vision-Assist, Kinect Camera, Auditory Assistance, Obstacle Detection

1. Introduction

Visually impaired people often suffer from some deprivation, which affects them physiologically and psychologically. An estimate done back in 2007 recorded that half a million Canadians have significant vision loss and around 5.5 million have major eye disease which could lead to eye damage, which directly influences their quality of life. The National Coalition for Vision Health report indicates a potential crisis in Canada in eye health care. Moreover, vision loss is increasing at an alarming rate in Canada [1]. According to the World Health Organization (fact sheet number 282) in 2014, 285 million individuals are estimated to be visually impaired around the world [2]. In last three decades, many solutions have been proposed and were made available to the blind users through various sources such as white canes, laser canes, binaural sensing aids, Braille and guide dogs for blind people.

The primary requirement of any aid is to detect the obstacle which cannot be sensed through touch or hearing. Furthermore, unforeseen obstacles in various routine tasks planning severely hinder the navigation of the blind individual. The circumstances above lead to user's unwillingness to travel and restrict themselves to a confined space despite having an aid [3]. Moreover, these aids are not foolproof and do not provide hassle free navigation assistance against all kinds of environments with different kinds of hazards and obstacles.

However, many people who got along with these visual aids found these to be helpful in day to day life. Blind people feel assistive technology trustworthy and useful for navigating [4].

To help blind people navigate, we need to detect the prompt environmental conditions for obstructions to travel. Moreover, exploring obstacles and hazards which the regular aids cannot notice. The visually impaired people does not have the freedom to navigate without assistance, as the information regarding the environment is not within the sensing limits of laser canes and ultrasonic obstacle avoiders [5]. Navigation systems for blind have been proposed in order to increase the mobility of the blind. However, they were only concerned with guiding the user along a predefined route [6]. In this study the guidance performance was evaluated in virtual display mode for this study. A group of researchers aimed to provide blind people as much information about their immediate environment, by capturing the form and the volume of the space in front of the blind person and direct the user in the shape of a sound map using headphones in real time [7]. These studies are based on the creation of virtual acoustic space (VAS) [8] giving the person more independence of orientation and mobility. Fundamentally, VAS is the perception of space using only sound.

Electronic Travel Aids (ETA), have been used by researchers in the past [9] as an assistive device which transforms the environment surroundings into another sensory modality. These aids have proven to help visually impaired people navigate with high confidence, physiologically and psychologically. These devices can detect obstacles in the path of the user. ETAs have three building blocks, the sensors, software interface, and a feedback mechanism. The sensors transmit the data to the system, which is further processed using the designed software and informs the user with the surrounding information, and a real-time feedback so that there are no hindrances in the user way.

Borenstein et al. [10], and Dodds et al. [11] used ultrasonic sensors to augment the performance of the guide cane. Theses sensors helped the user to detect barriers and steer accordingly, which proved better as compared to usual cane, as guide cane provided path easily and without much efforts. Benjamin et al. [12], and Yuan et al. [13] used laser and vision sensors that enhanced user's confidence while navigating and was a reasonable mode for providing high information in real time using laser triangulation system. In 2011 S. T. Brassai et al. [14] provided an overview of the literature available on assistive technologies with the focus on aspects such as assistance device for the daily life use and indoor/outdoor navigation in a dynamic environment. They also provided the list of solutions available for helping visually impaired people, such as navigation system, obstacle avoidance, and obstacle localization.

Developing a computer aided tool/vision system is another solution to assist the blind user and is still a developing area. The aim of most of the available systems is to provide help to visually impaired people without any secondary help. In a survey done by B. Sujith et al. [15] in 2014, proposed a new framework by overviewing the essential aspects which will help visually impaired individuals and additionally provided possibilities of some other capabilities for better results. They also listed some challenges in various areas which still require further research and development. The evaluation and comparisons made in this study stated that for obstacle detection, image processing has a major role. Furthermore, they also proposed a scheme for the other capabilities such as obstacle detection, object identification, path and door detection, feature extraction for various objects, and digital reading contents. All these capabilities mentioned above need to have an excellent image processing techniques and gesture recognition.

Indoor auditory navigation system [16] presented by A. Zeb et al. in their study assists blind and visually impaired people, using computer vision and markers in the environment. The user navigates in the surrounding environment using a webcam attached to the system. Whenever web camera detects a particular marker, audio assistance provides the user, with valuable information that enables them to navigate independently in the environment.

C. K. Lakde et al. reviewed [17] and further designed the system [18] that help or guide people. This main idea behind this study is to make a person aware of the path and the obstacles in the path. The proposed system consists of sensors (depth and RGB sensors) embedded in shoes, control board and a response system (vibration and voice assistance). An Ultrasonic Assistive Headset was developed by Ş. Aymaz et al. [19] for visually impaired and blind people. This headset guides user for obstacles using ultrasonic sensors, microcontrollers, voice storage circuit and solar panels. This device can be utilized both indoors and outdoors and can avoid obstacles quickly and accurately. In their study, A. Joshi et al. [20] used Simultaneous Localization and Mapping Algorithm (SLAM) visually impaired people for outdoor navigation. They used Android based mobile phone having sensors such as an accelerometer, gyroscope, proximity and ambient light sensor. An application based on death reckoning SLAM algorithm is used for tracking and alerting user for obstacles. Vibration to audio signals was used to assist the blind person to follow the appropriate path. Another research presented by T. Schwarze et al. [21], a wearable assistance system for helping visually impaired people. The system uses a stereo camera and sends acoustic feedbacks. The experimental study uses basic scene understanding, head tracking, and sonification that allows the user to walk in an unfamiliar environment and to avoid obstacles safely. There have been a lot many solutions provided by various researchers to help address these problems, but much of those are just limited to certain area.

2. Methodology

2.1. System Configuration: Microsoft Kinect

Technological innovations led to Microsoft Kinect for Xbox 360, a motion sensing device for a video game consoles. Onboard it has depth sensor, IR emitter, RGB camera, multi-array microphone and a motorized tilt. RGB (i.e. red, blue and green) and depth streams use 8 bit and 11 bit VGA resolution video stream [22].

The color sensor captures and streams the color video data at 30 frames per second (FPS) with a resolution of 640 × 480 pixels or 1280 × 1024 at a lower frame rate. The field of view (FOV) for the camera ranges from 57 degrees horizontal and 47 degrees vertical. Kinect is capable of generating an image-based 3D reconstruction of an object or a scene. The processing is done using depth data with a stream resolution of 640 × 480 pixels. Kinect can capture a user standing between 0.8 meters and 4 meters which are the depth sensor range.

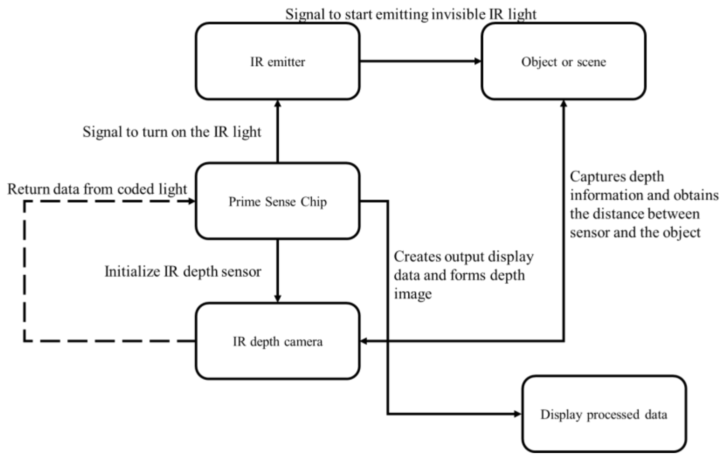

Fig. 1: Kinect Depth Data Processing.

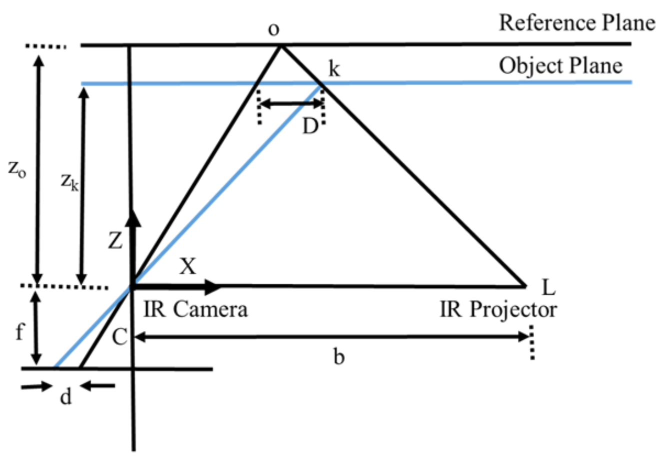

Fig. 2: Schematic representation of Triangulation method.

The Kinect depth image data is displayed on the output screen by the process shown in figure 1. [23] The Prime sense chip sends a signal to the IR projector to start emitting an invisible electromagnetic light onto the object or the scene. It also sends the signal to IR depth sensor to initialize and capture the depth stream and this information is sent back to the chip where the frame by frame depth stream is created for the display.

A Kinect camera uses triangulation method for measuring the depth of objects. The IR projector projects the laser pattern which gets reflected by the object in the sensing range and IR camera triangulates it for depth map by recapturing the emitted light as shown in figure 2.

The ratio of disparity D and depth distance d may be obtained as [24, 25]:

$$\frac{D}{b} = \frac{(z_o - z_k)}{z_o} \tag{1}$$

The coordinate system has its origin at the centre of the IR camera. Z and X axis are perpendicular to each other. b is the baseline between the IR camera and the IR projector, z_o is the assumed position of the object on the reference plane, and z_k denotes the depth or the distance of point k in object space. In Equation 1, D is the displacement of k in object space or the disparity of object's position between the reference and the object plane.

Further, the ratio of intrinsic parameters and depth parameter is given by.

$$\frac{d}{f} = \frac{D}{z_k} \tag{2}$$

Where, d is the depth distance/ observed disparity, and f is the focal length of the Infrared Camera. Equation 3 denotes the observed disparity where z_o, f and b can be determined by calibration.

By substituting D from equation 2 into 1 and expressing zk in terms of other variables, z_k is obtained:

$$z_k = \frac{z_\circ}{1 + \frac{z_\circ}{f \times b} d} \tag{3}$$

2.2. Software Design and Implementation

In this study, a computer vision system for navigation is proposed which is not limited to the sensor itself; it comprises of three main components. These components have their unique functionality, first Microsoft Xbox 360 Kinect sensor, used for collecting the environmental information (both depth images and RGB images). The second is the image processing algorithm written in C sharp language, performed on a laptop, and the final element, a Feedback system which assists the visually impaired person in navigation by providing directional information through auditory output using Bluetooth earphones.

When the system runs the algorithm, Kinect sensor starts capturing the depth and RGB data within the vertical and horizontal range of the sensor. This data is then sent back to the laptop for image processing in real time without any noticeable time delay and provides useful directional feedback to the user through the connected Bluetooth earphones. The Kinect sensor, shown in Figure 3 shows the person equipped with the kit, where the sensor is mounted on the chest using GoPro chest mount right at the centre which makes it robust, portable and stable. The Kinect is powered by chargeable 6000 mAh Li-Ion, 12V DC portable battery pack which can power the system for almost 8 to 10 hours. The image processing is being performed on the Laptop in the backpack.

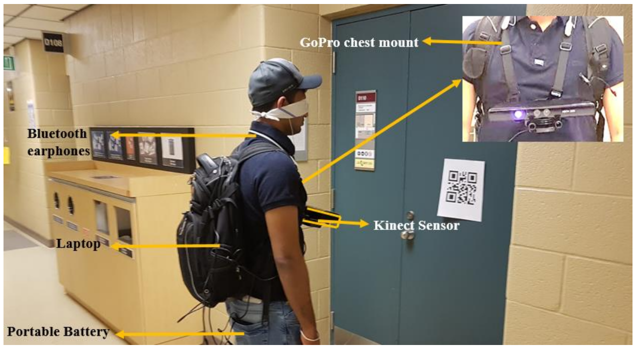

Fig. 3: Person equipped with the system.

This prototype system provides better vision as compared to the conventional cheap sensors as these cannot produce the same quality output for various data. This study is implemented and tested using the Kinect sensor, which is a robust system containing an infrared sensor, infrared projector, a microphone array, and an RGB camera. The algorithm helps in processing the data from video captures from the sensor in real-time, and all these processes are running on a laptop. The processed data further guides the user to navigate with the aid of auditory outputs providing good directional messages about the surroundings. This device provides the user with a better understanding of the surroundings. Moreover, it is a reliable, painless and inexpensive method to help navigate and provides the user with the right amount of information for navigating indoors. Specific scenarios experimented, to help the user navigate and the approach has test results using the Kinect.

Three main scenarios tested in this study are,

1. Navigate indoors such as in classrooms and laboratories, guiding the visually impaired person through obstacles such as tables, chairs, lab partitions, other individuals and cabins.
2. To detect the doors and name the classrooms and labs by their names or numbers while in the hallways or corridors and to recognize stairway going up or down.
3. Follow a specific person out of three in the lobby, with audio guidance through Bluetooth headphones.

For the above-mentioned testing scenario's, the system is designed for two different modes of guidance in accordance to the needs of the visually impaired person. In the Normal Mode of guidance, the user can roam freely indoors and make their way to their destination, where they would be informed about obstacles (both on ground or hanging), persons in their way, as well as stairs. Moreover, if in some case they do not receive a precise information, they are backed up with Quick Response Code (QR) which are put on at various locations in the building premises. These codes are readable much faster and can store a significant amount of information. Moreover, the user can get information such as stairs going down/up and a number of stairs, elevator and level information. The other mode of guidance which is novelty of this study is Follow Mode; in this mode, the visually impaired person can follow a particular person for navigational help and it would provide assistance will not be altered even if anyone is in the range of the sensor.

Figure 4 shows the configuration of the system. The algorithm used for image processing converts the data from the depth and RGB images, pixel by pixel, into various surface features as shown in the system configuration. It is then further processed and segmented into separate regions, and then it looks for the scene entities in these areas. Then these scenes are divided into left, centre and right region to assist the user which way to go avoiding all kinds of obstacles. QR code algorithm helps to scan various codes using in our study which store all the relevant data which the Kinect sensor can miss out; such as the depth data for stairs or number of stairs, elevator information, lab and classroom numbers. In the Follow

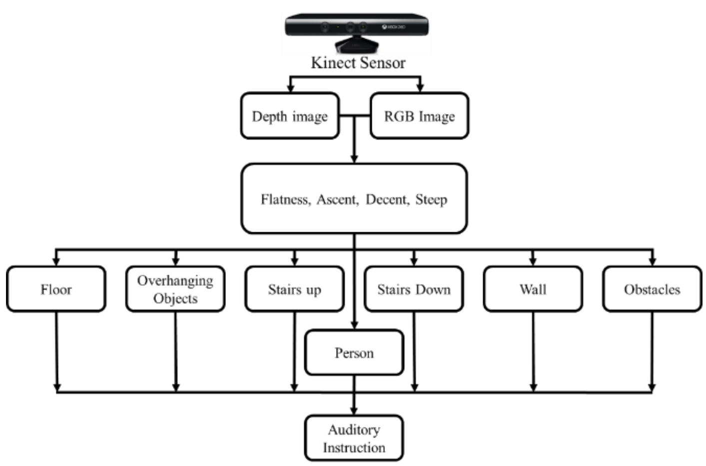

Fig. 4: System Configuration [26].

mode, the depth camera is used with the help of image processing and skeleton tracking based approach to follow the nearest person to the camera. The sensor will not take account of other people passing through and will guide the user accordingly.

3. Results and Experimentation

A total of six users participated in this experimental study using both normal or free mode guidance and follow mode guidance. Each user carried out two trials for the path specified for the system testing, which means a total of twelve trials were conducted for each mode. The blinded person starts from a lab on the level 2 on free mode as shown in Figure 5.

Then the individual must take an exit from the lab by avoiding all the obstacles on their way to the exit door. QR codes pasted on the door give feedback to the user saying exit. Once the user is out from the lab, they turn right towards the elevators or go straight towards the stairway. QR codes which assist the user and give them feedback about the number of stairs and up or down. From level 2 now the user must go down to level 1 and walk through the hallways which have many classrooms and labs. QR codes will assist the user about their final destination.

In follow mode guidance, shown in figure 6, the user will just keep on following a particular person in the indoor environment. In this mode we assume that there are not more than three individuals walking in the hallway and following that person the user will reach its destination by getting auditory feedback about each and every movement in the form of directional guidance. The person being followed is highlighted by red box as seen in the image, system will guide the user accordingly and at the same time let the user know about obstacles.

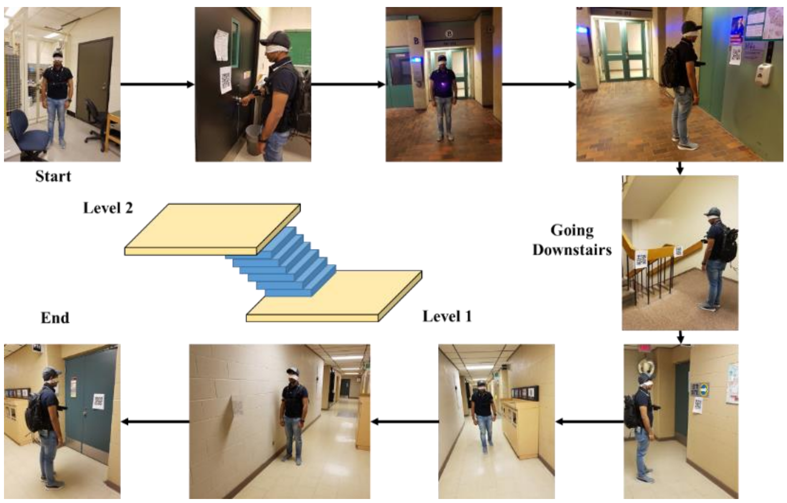

Fig. 5: Experimental Environment for normal mode guidance.

In the final part, we conducted some interviews with individuals (Normal human with blindfold) who were the part of experimentation and used our prototype and answered various questions regarding our assistive technology and how they felt while testing it as the part of the project.

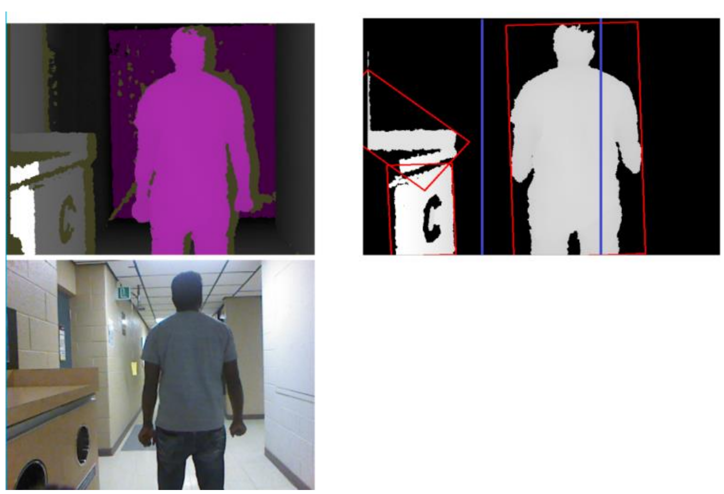
Fig. 6: Processing for Follow mode guidance

Our System provides visually impaired users with the ability to navigate in an indoor environment. The obstacle test course as discussed above and provides an answer to the questions regarding navigation for the blind. A total of six sighted people were part of the testing, due to easy availability and accessibility to test. This testing also helped in improving our device with further iterations. All this improved our system implementation. The efficiency and the effectiveness of the device was measured by feedbacks from the blindfolded participants. Significantly the usefulness of the device is measured by the effectiveness to avoid the obstacles. However, there were few instances as shown in the above figure 7 where the user was not able to detect chairs, other obstacles, elevators and stairs. This is due to the limited range of the Kinect sensor and its positioning when equipped by the user, as it might not cover the obstacles outside its range or viewing angle and sometimes miss out on reading a QR code on their way.

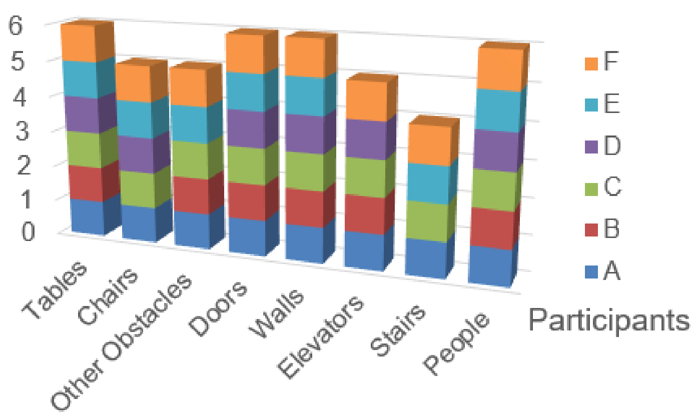

Fig. 7: Table showing Prototype testing for blindfolded sighted participants.

The testing was performed under some assumptions such as not more than three people in the path of the user, and most of the obstacles except the humans are stationary. The participants found the device easy to use and more accurate for detecting obstacles and following a person. All the participating users found the prototype/ this assistive technology to be helpful and can be relied on for navigation.

4. Conclusion & Future Work

This paper presents an indoor navigation system using a Kinect sensor, for free and follow mode guidance. The system designed is durable, lightweight, and cost-effective, and anyone can use it with ease without any training because of its simplistic working. The real-time image processing helped to detect all kinds of obstacles such as tables, chairs, persons, walls, doors, and stairs. In our study, we also used QR codes for augmenting the power of our proposed system. The audio information is provided to the blind person whenever there is some obstacle or QR is scanned by the camera and even for the follow mode for directional information. The system was evaluated by six blindfolded users in both types of navigation modes. The conclusion obtained from the results clearly show the effectiveness and efficiency of our system in helping visually impaired users in the indoor environment.

Having created a successful prototype that can assist blind or visually impaired, there is further scope for improvement. The next steps are to build a more stable mount for the camera, for better viewing angles and calibration. The new version of Kinect can also be brought into use with all new technology and better quality camera. These would increase the scanning range of obstacles. There is also a possibility of using multiple Kinect sensors that might help to provide more independence while navigating and there might be few changes in the algorithm to make it more robust. The future iterations to this will keep on augmenting the use of this device.

References

[1] Fast Facts about Vision Loss. [Online]. Available: http://www.cnib.ca/en/about/media/vision-loss/Pages/default.aspx

[2] Visual impairment and blindness, 2014. [Online]. Available: http://www.who.int/mediacentre/factsheets/fs282/en/

[3] R. G. Golledge, J. R. Marston, and C. M. Costanzo, "Attitudes of Visually Impaired Persons Toward the use of Public Transportation," Federal Reserve Bank of St Louis, St. Louis, Business Premium Collection, 2001. [Online]. Available: https://search.proquest.com/docview/1698152341?accountid=14701

[4] T. Morton and M. Yousuf, "Technological innovations in transportation for people with disabilities workshop summary report," 2011.

[5] J. Brabyn, "Developments in electronic aids for the blind and visually impaired*," IEEE Engineering in medicine and biology magazine*, vol. 4, no. 4, pp. 33-37, 1985.

[6] J. M. Loomis, R. G. Golledge, and R. L. Klatzky, "Navigation system for the blind: Auditory display modes and guidance," *Presence: Teleoperators and Virtual Environments*, vol. 7, no. 2, pp. 193-203, 1998.

[7] J. L. González-Mora, A. Rodriguez-Hernandez, L. Rodriguez-Ramos, L. Díaz-Saco, and N. Sosa, "Development of a new space perception system for blind people, based on the creation of a virtual acoustic space," *International Work-Conference on Artificial Neural Networks*, pp. 321-330, 1999.

[8] J. L. González-Mora, A. Rodriguez-Hernandez, E. Burunat, F. Martin, and M. A. Castellano, "Seeing the world by hearing: Virtual Acoustic Space (VAS) a new space perception system for blind people," *Information and Communication Technologies, 2006. ICTTA'06*, vol. 1, pp. 837-842, 2006.

[9] S. Ram, Jennie Sharf, "The people sensor: a mobility aid for the visually impaired," *Wearable Computers, Digest of Papers. Second International Symposium on. IEEE*, 1998.

[10] J. Borenstein, I. Ulrich, "The guide cane-a computerized travel aid for the active guidance of blind pedestrians," *Proceedings of IEEE International Conference on Robotics and Automation*, vol. 2, 1997.

[11] A. G. Dodds, "The Sonic Pathfinder: An Evaluation," *Journal of Visual Impairment and Blindness*, vol. 78, no. 5, pp. 203-6, 1984.

[12] J. M. Benjamin, N. A. Ali, and A. F. Schepis, "A laser cane for the blind," in *Proceedings of the San Diego Biomedical Symposium*, vol. 12, no. 53-57, 1973.

[13] D. Yuan, and R. Manduchi, "Dynamic environment exploration using a virtual white cane," *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, vol. 1, 2005.

[14] S. T. Brassai, L. Bako, and L. Losonczi, "Assistive technologies for visually impaired people," *Acta Universitatis Sapientiae: Electrical and Mechanical Engineering*, vol. 3, pp. 39-50, 2011.

[15] B. Sujith and V. Safeeda, "Computer Vision-Based Aid for the Visually Impaired Persons- A Survey And Proposing New Framework," *International Journal of Innovative Research in Computer and Communication Engineering*, 2014.

[16] A. Zeb, S. Ullah, and I. Rabbi, "Indoor vision-based auditory assistance for blind people in semi controlled environments," *4th International Conference on Image Processing Theory, Tools and Applications (IPTA)*, pp. 1-6, 2014.

[17] C. K. Lakde and P. S. Prasad, "Review paper on navigation system for visually impaired people," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 4, no. 1, pp. 2278-1021, 2015.

[18] C. K. Lakde and P. S. Prasad, "Navigation system for visually impaired people," *International Conference on Computation of Power, Energy Information and Commuincation (ICCPEIC)*, pp. 0093-0098, 2015.

[19] Ş. Aymaz and T. Çavdar, "Ultrasonic Assistive Headset for visually impaired people," *39th International Conference on Telecommunications and Signal Processing (TSP)*, pp. 388-391, 2016.

[20] A. Joshi, H. Agrawal, and P. Agrawal, "Simultaneous Localization and Mapping for Visually Impaired People for Outdoor Environment," in *Proceedings of the Second International Conference on Computer and Communication Technologies*, pp. 107-115, 2016.

[21] T. Schwarze, M. Lauer, M. Schwaab, M. Romanovas, S. Böhm, and T. Jürgensohn, "A camera-based mobility aid for visually impaired people," *KI-Künstliche Intelligenz*, vol. 30, no. 1, pp. 29-36, 2016.

[22] Kinect sensor for Xbox 360 components. [Online]. Available: https://support.xbox.com/en-US/xbox-360/accessories/kinect-sensor-components

[23] K. Sharma, "Kinect Sensor based Object Feature Estimation in Depth Images*," International Journal of Signal Processing, Image Processing and Pattern Recognition*, vol. 8, no. 12, pp. 237-246, 2015.

[24] A. Khongma, et al, "Kinect Quality Enhancement for Triangular Mesh Reconstruction with a Medical Image Application," *Soft Computing Techniques in Engineering Applications. Springer International Publishing*. 15-32, 2014.

[25] K. Khoshelham, "Accuracy analysis of kinect depth data," *ISPRS workshop laser scanning*., vol. 38, no. 5, 2011.
[26] D.-M. Tsai, H. Hsu, and W.-Y. Chiu, "3-D vision-assist guidance for robots or the visually impaired," *Industrial Robot: An International Journal*, vol. 41, no. 4, pp. 351-364, 2014.