LITERATURE REVIEW

INTRODUCTION

Visual impairment and some varying degrees of blindness were widespread in the ancient Greco-Roman World[1]. The significance of the classical antiquity, the work has largely focused on the proof from the Greek world. There is an uncanny popularity of various artists with visual impairment as it is told that it heightens the other senses. The blind bard Homer, the blind seer Teiresias and the blind king Oedipus are the of those well-known characters in our history. It follows those modern scholarships on blindness focuses a great deal on these famous characters.

The technical definition of the blindness is the absence of light perception. It can be either partial or complete. Partial blindness means very limited vision whereas complete blindness means you cannot see anything or do not see light. Vision loss happens suddenly or over a period of time. People with vision that is worse than 20/200, even with glasses or contact lenses, are considered legally blind in most of the US. Though no agreement has ever been reached on a standard definition that would encompasses all persons severely handicapped by visual loss. In 1972, 441000 to 1700000 were legally blind in the United States[2]. Considering most of the statistical data, 62% has cataract, 19.7% has visual impairment because of refractive error, 5.8% has glaucoma and 1% has corneal disease. World Health Organization (WHO) estimates that 80% of visual impairment is either preventable or curable with treatment.

STATISTICAL RECORDS:

Any kind of visual impairment can be a result of severe accidental injury or gradual degradation of visual acuity. Even in serious illness, it is very difficult to figure out the answer as to whether the disruption occurs primarily in the brain or in the precortical areas of visual perception[3]. In a study[4] to find the causes of blindness and vision impairments between the years 1990 to 2020, the systematic review and meta-analysis of population-based survey (of adults older than 50 years) used two terms to characterize the visual impairment, one is obviously, Blindness and other as moderate to severe visual impairment (MSVI). Blindness was characterized when the visual acuity was <3/60 or has <10 degrees of visual field of view whereas MSVI was characterized when the visual acuity is <6/18 to 3/60. The results didn't show much of a difference, there was only a change of 0.2% - 0.5% in MSVI whereas age standardized prevalence of avoidable blindness decreased by 15.4%.

In the year 2020, the leading cause of blindness[4] was cataract (15.2 million) followed by glaucoma (3.6 million) then untreated refractive error (2.3 million), age related macular degeneration (1.8 million) and diabetic retinopathy (0.86 million) and the leading cause of moderate to severe visual impairment (MSVI) are Untreated refractive error (86.1 million) and cataract (78.8 million). There was a distinct catch in the study that, the count for myopic macular degeneration was extremely high in China[5], so there was a different study just to get the absolute data. The reason for taking adults over 50 years was because the data for children and younger adults is very diverse and sparse which will not give any proper collective result.

HISTORY OF ASSISTIVE TECHNOLGY AND EVOLUTION:

The first assistive aid was invented 200 years ago[6] and electronically developed technology was used 50 years ago around 1970s. The first technology for individuals with low vision was magnifying glass and for blindness was braille. Even though the first eye glasses which were there from 1000 AD was in the form of handheld lenses. Head borne eyeglasses was first invented in Italy (1285) and after the invention of printing press (1456), there was a final evolution mark for the eye glasses. The first school for blind students was established by Valentin Hauy[7] in France in spring 1784, where, Louis Braille became the youngest student at the age of 10. In October 1824, Braille (creator of the technology Braille) found 63 ways to arrange a six dot cell that helped him create the entire Braille system[8]. Eventually with time, there was the invention of Braille press for the higher ups in the society who were visually challenged but wanted to convey through writings. In 1969, the first prototype braille display was developed by Argonne NL.

AT DEVICES FOR VISUALLY IMPAIRED IMDIVIDUALS:

As we know assistive technology is a generalized form of technology, devices, services, systems, processes, and ambience changes used by individuals with disability to overcome barriers in of society, infrastructure and to actively participate in daily activities with ease and safety. Any AT device for visual impairment can be divided into three categories containing AT devices for daily living, AT devices and technology for orientation and perception, and AT technology for learning.

Labelling system[9] is an important way to assist people with lower visual acuity to identify different elements of things in their life. Labelling can also be grouped as Tactile labelling system, which is based on different alphabets used for visually impaired like Braille, Barcode Labelling System, where a beam of light is used to the barcode to be read. Radio frequency identification labelling system is used whereby a tag is given to each item and then the tag is read by the reader using the radio signal.

Health Care Monitoring System[10] is to assist visually impaired people in monitoring their health such as Talking blood pressure meter, talking blood glucose meter, tactile watch with provision of output in the form of Braille and carbon monoxide monitor.

Food preparation and Consumption plays a vital role in an individual’s life. There are numerous devices which helps people with visual impairments, such as talking kitchen thermometer and weighing scales.

Environmental and financial assists include talking barometers, dryer, washing machines, currency distinguishers etc.

The most important and vital parameter for a human being is their mobility and guidance. So, technology has gifted a numerous amount of ideas to the world in navigation to help people to make sure they are in proper orientation, route selection, obstacle prediction and when to avoid it.

Electronic travelling aids (ETA)[11] contains obstacle avoidance systems, motion planning and monitoring, such as Ultra cane. It mimics the process of rays of bats and dolphins and how they can communicate and detect obstacle. It emits ultrasound in two modes, the short range and the long-range modes. There are two in the handle of the cane which vibrates at different intensities to indicate an object proximity and position. Lower-level objects in front of the person is detected by lower tactile button, while the upper-level tactile button is used when the object is above the waist. Another advanced device used to assist the visually impaired is the Bionic eye system, which consists of a pair of glasses with small video camera mounted on it which capture the image. A small prosthesis is implanted on the surface of the retina, and the information from the camera is transmitted wirelessly to electrode on the artificial retina and it is converted to electrical pulses.

Electronic Orientation Aids (EOA)[11][12] are designed to provide orientation to blind and partially blind people. They provide with the information such as location, direction, and constraints in the observer's environment. One of the major uses of this is in buses and train stations such as RNIB REACT system. It speaks a message as a visually impaired individual walks up to it. They can then follow the spoken instructions to find the way to their required destinations. GPS devices available for blind people are the ones, which give message in the form of voice by telling them the directions and following the next steps. The user then uses their mobility skills to reach to their destinations.

AT devices for learnings are used by students who face challenges in their educational environment. The AT devices/aids are divided into two categories, such as AT devices for reading and AT devices for writing. Braille[8] has been one of the most popular AT devices which helps students to learn and read through many generations. It is a system of touch readings and writing for blind people where embossed dots represent the letters of the alphabet. Audio book is also a good example of AT reading device which is useful for not only visually impaired people but also for any individual who wants to take a break from reading and listen to the content as a story. As for writing, Braille note taker[13] has been very useful as it is a portable word processing device that uses eight key Braille input to use them as writing a character of the alphabet. CCTV[14] (Close circuit television) allows magnification of the writing for the partially visual impaired individuals.

Lastly, service animals have been a great help to the people with visual impairments to help them guide through the environment and having a company helps them to be mentally optimistic whilst doing the daily activities.

MECHANISM OF THE AT DEVICES:[15]

The development of assistive technological devices for visually impaired has helped them address multiple challenges they face in their day-to-day life. From obstacle detection to navigation of their routes to scene descriptions, text readings, facial recognitions and so on. It uses systematic mapping, which is mainly focused on the scene understanding concept. Concepts of deep learning with computer vision helps in getting the most accurate and better control of the trajectory planning for the AT devices. The reason for choosing computer vision approach to develop and review the assistive device is to understand the principle and law of creating this systematic mapping approach. Only a limited number of research has been done on this very particular field. The solutions they progressed are based on mostly using computer vision and speech recognition to bring in an audio based augmented reality experience for the users. For systematic mapping study, the most important requirement is the information of the surrounding environment. Scene understanding, assistance services, and evaluation are the parameters that was vastly of the coined importance for the research. We need a very high level of perception to get the understanding of the scene. The second step comes as how the knowledge of the outside world by the system is going to assist blind users and finally the evaluation category collects all the information about the way in the which it is evaluated. For the scene understanding, we need to create an autonomous exploration map where the accuracy of the contrast and brightness is not that necessary as much as the dimensions and edges. A few years back, image processing was used widely to make the images more perceivable for the user, but eventually with their basic limitations of the algorithms adding too much of noise to the image or amplifying the contrast were redundant for the aim. Lately, object recognition which is way more efficient method as to define the object and saving a lot of time with minute errors. To detect obstacles in the environment, we use sensors like LIDAR or Infrared triangulation or RGB techniques. They define the distance of the object from the source i.e.., the user.

Camera Based Techniques for obstacle detection is a method mostly used by autonomous vehicles, to help visually impaired people to navigate in an environment. Stixels[16] algorithm provides ambience awareness of the depth images provided by an RGB D camera. These images are captured using the cameras that work with sensors for distance calculation. Stixels segment objects in the image around the user in vertical regions according to their depth disparity in the environment. Afterward, using object recognition techniques, Stixels semantically categorize objects in the scene.

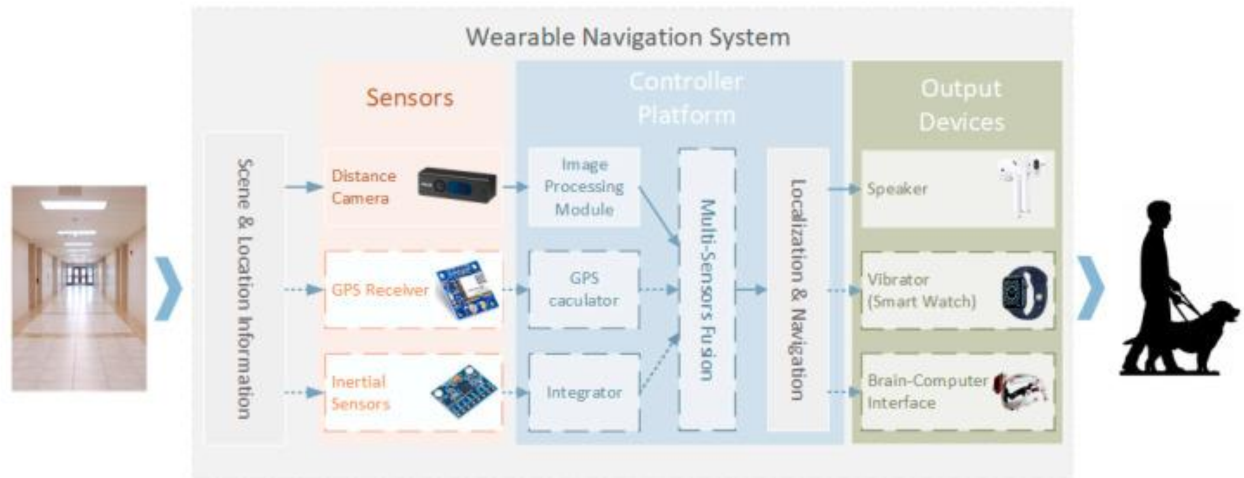
Distance based techniques sometimes uses mathematical method of using depth images and fuzzy control logic[17] for the approximate measurements of the obstacle's distance. The solution is divided into three parts which categorizes the location of obstacles in three different way and provides feedback for the user according to them. For the user facing the obstacles, the system makes decisions in order to avoid them based on 18 different fuzzy navigation roles that depend on the location of the obstacles. As for the sensory approach, we use ultrasonic sensor to measure the location and distance of the object as it is comparatively cheap with lower power consumption. They have transmitters that generates sound waves, and the receiver of the sensors waits for the rebound of the sound. The only limitation is that they cover shorted distances, and they are better at detecting transparent objects which makes it more suitable for indoor environments. Lately to advance upon, researchers and scientists have been using combined techniques of camera and sensor to get more of the accurate data.

For object recognition, engineers have been using deep neural networks for the object detection with the latest convoluted neural network models (CNN)[18][27]. They have better performance which makes real time object recognition more achievable. CNN can learn high level semantic features from the input data and optimize multiple tasks simultaneously like regression and classification of the images. We use cloud services lately to execute the process of recognition. Important thing to note is that the quality of the images sent to the algorithms can affect their performance with images taken at night might have higher noise level or distortion which can reduce the accuracy of the model.

It is very crucial to consider on how the information regarding the environment obtained by the sensors, cameras and the algorithms is transferred. They required assistance provided has to be smooth, accurate and understandable. The feedback modality is highly based on audio and tactile feedback. Researchers use binaural audio[19] for scene description, which brings a sense of audio-based AR to the user. Users can hear and feel the approximated 3D location of the obstacle based on the audio they hear using bone conducting[20] earpieces or headphones. Earlier the feedback used to be vibrating i.e.., haptic feedback or an audio beep or label sound. The pitch or base of the sound changes according to the proximity of the object. Additionally customized text detection, GPS tracking for live location, face recognition modules were added. Considering the main relevant categories, mobility and self-care were taken to be of high importance and solution are made to resolve these two contexts.

DESIRED ASSISTIVE TECHNOLOGY SOLUTION CONCEPT:[21][22]

The wearable device uses semantic visual SLAM (simultaneous localization and mapping) technique with image depth RGB D camera sensor as the controlled sensor. This not only determines the position posture and trajectory but also establish a goal map in real time. In this device, the mechanism is very simple as of the other advanced technological devices, it gets the defined prior map which is established by the SLAM[23][24] process of a robot but with RGB-D cameras, realizing real time navigation can be done without prior mapping through SLAM. New proposed solutions also use text and voice recognition to determine the goal destination. During the 3D semantic scheme establishment, the information labels were tagged by the decision-level tree random forest. After building the wearable navigation system, the data structure of the map points is extended by probability fusion. The speed evaluation is done using the TUM RGB-D database. The localization error found to be of 5cm. We achieved more precise and accurate navigation[26] through the combination of IMU (indoor) and GPS (outdoor) to reduce errors.



Fig[21]. System structure for wearable navigation system.

This device[25] is considered to be lightweight, miniaturized and of integrated design having high precision cameras which can be used to develop wearable navigation devices. The user experience can be improved through developing navigation program and enhancing HCI (Human Computer Interaction). Interaction of the wearable device with the user should be as simple as possible hence using voice techniques.

CONCLUSION:

So, as we see that the impairment of visual acuity has been around since centuries or defined in the mythological epics. It has always been regarded as a disability and from the past few centuries, people have been trying to perfect the assistive devices to help people perceive the world around them. Since 1970s, the modern turn took place. From electronically advanced devices to devices with artificial intelligence were created. As my research is on the advancements in the field of image processing and computer vision, I focused on the newest technologies and the mechanism behind each of the steps to create a customized and advanced device for the visually impaired.

Appendix.

1. Trentin, L. (2013). "Exploring Visual Impairment in Ancient Rome". In *Disabilities in Roman Antiquity*. Leiden, The Netherlands: Brill. doi: https://doi.org/10.1163/9789004251250_006
2. The Unseen Minority: A Social History of Blindness in the United States by Frances Koestler
3. Adámek, P., Langová, V. & Horáček, J. Early-stage visual perception impairment in schizophrenia, bottom-up and back again. *Schizophr* **8**, 27 (2022). https://doi.org/10.1038/s41537-022-00237-9
4. Lancet Glob Health. 2021 Feb; 9(2): e144–e160. Published online 2020 Dec 1, https://doi.org/10.1016%2FS2214-109X (20)30489-7
5. Zou M, Wang S, Chen A, et al, Prevalence of myopic macular degeneration worldwide: a systematic review and meta-analysis, British Journal of Ophthalmology 2020;104:1748-1754.
6. Anthony Candela, Legends and Pioneers of Blindness Assistive Technology part 3.
7. Valentin Haüy and Louis Braille: Enabling Education for the Blind, DOI: 10.1007/978-3-319-59641-9_5 In book: Foundations of Ophthalmology
8. Roth GA, Fee E. The invention of Braille. Am J Public Health. 2011 Mar;101(3):454. doi: 10.2105/AJPH.2010.200865. PMID: 21307377; PMCID: PMC3036681.
9. Coughlan JM, Shen H, Biggs B. Towards Accessible Audio Labeling of 3D Objects. J Technol Pers Disabil. 2020; 8:210-222. PMID: 32802916; PMCID: PMC7425180.
10. George Vasilev Angelov, Dimitar Petrov Nikolakov, Ivelina Nikolaeva Ruskova, Healthcare Sensing and Monitoring, Enhanced Living Environments, 2019, Volume 11369 ISBN: 978-3-030-10751-2
11. Hill, E. W., & Bradfield, A. L. (1986). Electronic Travel Aids for Blind Persons. Journal of Special Education Technology, 8(3), 31–42. https://doi.org/10.1177/016264348700800304
12. Deverell, L., Bhowmik, J., Al Mahmud, A., Lau, B. T., Islam, F. M. A., Sukunesan, S., McCarthy, C., & Meyer, D. (2021). Self-reported use of technology by orientation and mobility clients in Australia and Malaysia before the COVID-19 pandemic. British Journal of Visual Impairment, 0(0). https://doi.org/10.1177/02646196211019070
13. Portable electronic braille devices – An overview, AIP Conference Proceedings **2142**, 140018 (2019); https://doi.org/10.1063/1.5122531
14. Turner, P. J. (1976). The Place of CCTV in the Rehabilitation of the Low Vision Patient. Journal of Visual Impairment & Blindness, 70(5), 206–214. https://doi.org/10.1177/0145482X7607000507
15. Valipoor, M.M., de Antonio, A. Recent trends in computer vision-driven scene understanding for VI/blind users: a systematic mapping. Univ Access Inf Soc (2022). https://doi.org/10.1007/s10209-022-00868-w

16. Hernandez-Juarez, D., Schneider, L., Cebrian, P. et al. Slanted Stixels: A Way to Represent Steep Streets. Int J Comput Vis 127, 1643–1658 (2019). https://doi.org/10.1007/s11263-019-01226-9
17. Piero P. Bonissone, Kenneth H. Chiang, Fuzzy Logic Controllers: a Knowledge Based System View, IFAC Proceedings Volumes, Volume 25, Issue 28, 1992, Pages 321-326 ISSN 1474-6670, https://doi.org/10.1016/S1474-6670(17)49518-8.
18. S. Albawi, T. A. Mohammed and S. Al-Zawi, "Understanding of a convolutional neural network," 2017 International Conference on Engineering and Technology (ICET), 2017, pp. 1-6, doi: 10.1109/ICEngTechnol.2017.8308186.
19. Chaieb L, Wilpert EC, Reber TP, Fell J. Auditory beat stimulation and its effects on cognition and mood States. Front Psychiatry. 2015 May 12;6:70. doi: 10.3389/fpsyt.2015.00070. PMID: 26029120; PMCID: PMC4428073.
20. Granados, J., Hopper, M., & He, J. (2018). A Usability and Safety Study of Bone-Conduction Headphones During Driving while Listening to Audiobooks. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 62(1), 1373–1377. https://doi.org/10.1177/1541931218621313
21. Chen Z, Liu X, Kojima M, Huang Q, Arai T. A Wearable Navigation Device for Visually Impaired People Based on the Real-Time Semantic Visual SLAM System. Sensors (Basel). 2021 Feb 23;21(4):1536. doi: 10.3390/s21041536. PMID: 33672146; PMCID: PMC7926395.
22. Vamsi Krishna B., Aparna K. 2017 Artificial Intelligence and Evolutionary Computations in Engineering Systems. Springer; Singapore: 2018. IoT-Based Indoor Navigation Wearable System for Blind People; pp. 413–421.
23. Mur-Artal R., Tardós J.D. ORB-SLAM2: An Open-Source SLAM System for Monocular, Stereo, and RGB-D Cameras. IEEE Trans. Robot. 2017;33:1255–1262. doi: 10.1109/TRO.2017.2705103
24. Mur-Artal R., Montiel J.M.M., Tardós J.D. ORB-SLAM: A Versatile and Accurate Monocular SLAM System. IEEE Trans. Robot. 2015;31:1147–1163. doi: 10.1109/TRO.2015.2463671
25. Lee Y.H., Medioni G. RGB-D camera based wearable navigation system for the visually impaired. Comput. Vis. Image Underst. 2016;149:3–20. doi: 10.1016/j.cviu.2016.03.019.
26. Zhang X., Li B., Joseph S.L., Xiao J., Sun Y., Tian Y., Muñoz J.P., Yi C. A SLAM Based Semantic Indoor Navigation System for Visually Impaired Users; Proceedings of the 2015 IEEE International Conference on Systems; Man, and Cybernetics, Hong Kong, China. 9–12 October 2015; pp. 1458–1463
27. Chen L., Papandreou G., Kokkinos I., Murphy K., Yuille A.L. DeepLab: Semantic Image Segmentation with Deep Convolutional Nets, Atrous Convolution, and Fully Connected CRFs. IEEE Trans. Pattern Anal. Mach. Intell. 2018;40:834–848. doi: 10.1109/TPAMI.2017.2699184