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Novel Method of Obstacle Detection and Avoidance for Visually Impaired People

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Abstract*: Electronic mobility aid, transforms visual information to another sensory modality, has proved to be useful for visually impaired people to commute confidently and independently. With recent developments in technology, more visual information can be provided that can assist the user in the better way to avoid obstacles. The paper is focused on portable mobility aid prototype based on stereo imaging that can help user avoid collision with the obstacles. The algorithm is based on segmentation of disparity image to detect obstacles in each segment and identify probable path free of obstacles. The information about the free path is conveyed to the user with the help of two vibrotactile sensors. The prototype was tried on visually impaired users. The experiments were conducted in terms of detection of obstacles, avoidance of obstacles and walking speed of visually impaired user in closed area with different number of obstacles. We conclude that mobility aid prototype is potentially effective for visually impaired users.

***Keywords*: Visually Impaired, Mobility Aid, Stereo Imaging, Disparity, Vibrotactile**

I. INTRODUCTION

Vision impairment is often due to conditions such as diabetic retinopathy, muscular degeneration, and glaucoma. The visually impaired(VI) community is very diverse in terms of degree of vision loss, age, and abilities. Vision loss affects almost every activity of daily working. Walking, driving, reading, recognizing objects, people, places becomes difficult or almost impossible without vision. Lack of mobility is a severe concern for blind people. They find it extremely difficult to travel independently as they cannot determine their position and orientation in surrounding environment. [1]World Health Organization(WHO) carried out a survey in 2010 to estimate total number of visually impaired (VI) people in the world. According to this report, out of 6737 million people in world, 285 million people are visually impaired. Out of 285 million VI population, approximately 39 million people are completely blind and 246 million people have low vision. Figures clearly indicate that there is a need of advanced assistive aid that can help VI community.

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[2] Human mobility comprises orientation and navigation. Orientation can be thought of as knowledge of position with respect to the objects in the environment. Information about position, route planning is linked with orientation. Navigation is ability to move within the local environment. This involves information about stationary or moving obstacles in the surrounding, features of the floor etc. Electronic travel aids (ETA) have been designed for VI people which convert visual information into auditory or haptic feedback. Some ETAs only give indication of presence of obstacles and some along with detection of obstacles also indicate a direction in which user should travel to travel to avoid the obstacle. These devices typically use range sensors like ultrasound, sonar or stereo cameras. ETAs can be classified based on type of range sensor used and the type of feedback given to the user. ETAs like Guidecane[3], CyARM[4] use ultrasound sensors for detection of obstacles and vibrotactile sensors to provide feedback to the user. Navbelt[5] and FIU[6] use ultrasound sensor for obstacle detection and stereo headphones for feedback. The number of range sensors used in the device vary from two to eight. Some computer vision based ETAs like ENVS[7] , tactile vision system (TVS)[8] use stereo cameras for obstacle detection and vibrators for feedback. vOice[9], Visual acoustic space[10], NAVIG[11],use stereo headphones for feedback. The processing of the information acquired by sensors is performed on a laptop or single board computers. The present work proposes a design of portable mobility aid based on computer vision (CV) that can help detect obstacles in front of the user, calculate probable path free of obstacles and help navigate the user to avoid collision with an obstacle. Obstacle detection is achieved using calibrated stereo cameras. The stereo cameras capture the area in front of the user at a fixed frame rate. Disparity map is generated from these captured stereo images. Obstacle detection and avoidance algorithm segments the disparity map and analyses for all the nearest obstacle. If the nearest obstacle is in the current path of the user, the algorithm calculates a path free of obstacles from the disparity map and informs the user about the change in orientation using vibration pattern. The paper is organized as follows. Section 2 presents some of the recent state of the art navigation mobility aid and explains the hardware design of the proposed prototype. Section 3 explains the proposed algorithm and related techniques. Section 4 presents and discusses some results obtained. Finally, section 6 concludes the paper with some final remarks.

II. NAVIGATION MOBILITY AID PROTOTYPE

In this section, we describe in some detail the components of the mobility aid , and how these components are used to provide the desired functional capabilities. The prototype of the proposed mobility aid is as shown in figure 1.

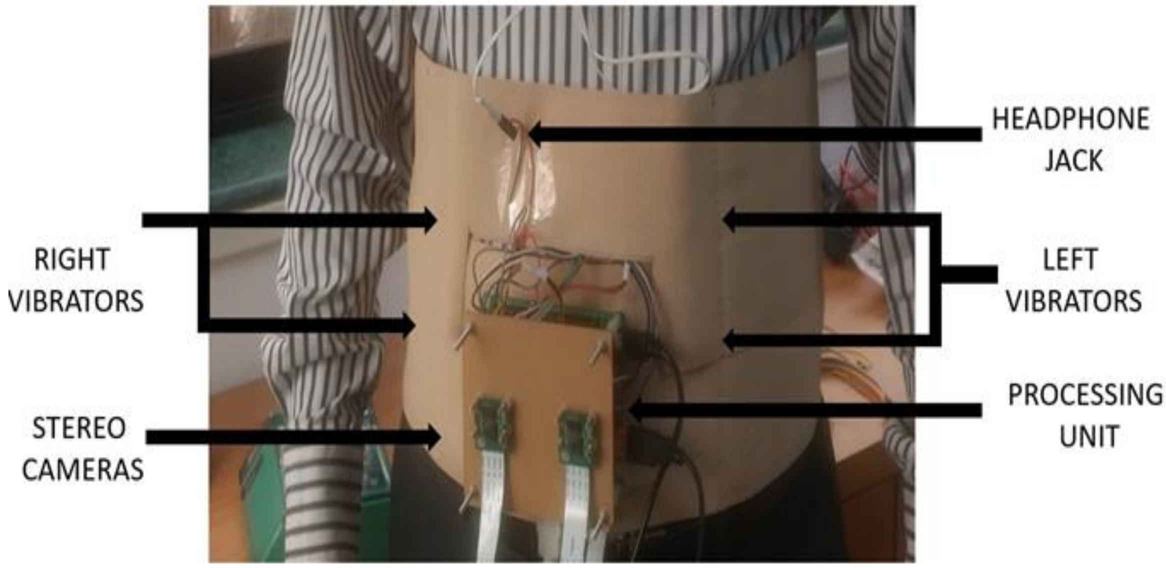

Figure 1: Hardware Prototype

In the mobility aid, two identical 5-megapixel camera era modules are used for data acquisition. Specifications of the camera modules are as given in the table 1. Interpupillary distance (IPD) is the distance between centers of the pupil[12]. IPD is an important measure in stereoscopic world. Statistics of ANSUR database of 2382 subjects suggest that the mean IDP for men is 64.67 mm and for women is 62.31 mm. Hence the distance between the two cameras in the prototype is 63 mm. Based on the sensors image area and focal length of the lens, the horizontal and vertical field of view is approximately 54° and 42◦ respectively. The processing of the stereo images is performed on a raspberry pi compute module[13]. The processing unit along with stereo cameras will be placed around the waist of the user using an orthopedic vest belt.

Table 1 : Camera Module Specification

Parameters	Values/Descriptions
Active array size	2592x1944
Output format	8/10-bit RGB data
Lens size	1/4”
Pixel size	1.4μm x 1.4μm
Sensor image area	3.6736mm x 2.7384mm
Focal length	3.6mm +=− 0.01
Focal ratio(f-stop)	2.9
S/N ratio	36db
Size	25x24x9 mm
Support for LED flash	Yes

This mobility aid is powered by 3500 mAh li-ion battery. Considering the average height of the user, and vertical field of view of the cameras, the prototype can detect all obstacles from ground level to head level height after a distance of 2 meters from the user. Navigation information is provided to the user using vibration pattern. The coin size vibrotactile sensors are fixed on the back side of the orthopedic vest belt. The arrangement of the vibrators on the belt are as shown in figure 2.

Figure 2: Arrangement of vibrators on orthopaedic blet

Vibration pattern is used to inform the user about the direction to be taken to avoid obstacle, if any, present in the current path of navigation of the user. Two left vibrators are used to inform the user to move left, and two right vibrators are used to inform the user to move right to avoid collision with the obstacle. Raspberry pi compute module uses raspbian linux operating system. The programming was done using python and OpenCV computer vision library. Cameras used in the prototype are not pre calibrated. We use 9*6 checkboard grid and OpenCV stereo camera calibration module to calculate the rectification matrix for each camera[14]. The calibration process is done every time the prototype is turned on. The software architecture of the prototype is as shown in the figure 3.

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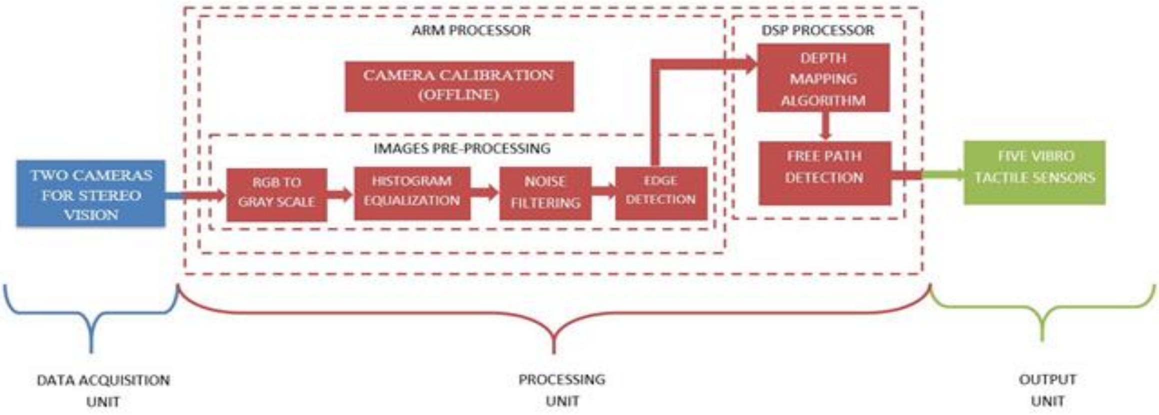

Figure 3: Block Diagram of Mobiity aid algorithm

Two 5-megapixel cameras are used to capture the surroundings in front of the user. These cameras capture stereo images at a rate of 1 frame/second and each camera generates a colored image of size 640*480*3. As shown in the software architecture, pre-processing is performed on the captured stereo images[15]. This pre-processing involves:

1. image rectification using rectification matrix generated by the calibration process.
2. RGB to gray scale conversion to reduce the computation load on the hardware
3. Histogram equalization to increase the accuracy of correspondence process in disparity mapping.
4. Bilateral filtering to remove noise and enhance the edge information in the captures images.
5. Canny edge detection to retain
6. the edges and remove the unwanted information.

Disparity map refers to actual pixel difference between a pair of stereo images. Disparity map algorithm establishes correspondence between the left camera image and right camera image. This algorithm architecture is as shown in figure 4 .

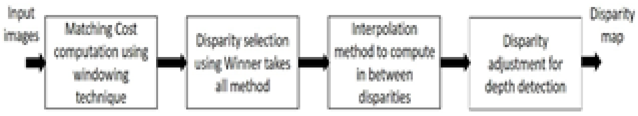

Figure 4: Disparity mapping algorithm architecture

To increase the speed of computation, cost computation algorithm is performed on edge detected stereo images. There are many correspondence algorithms, we use Sum of absolute difference(SAD) algorithm. The equation is as given below:

$$SAD(x,y,d) = \sum_{(x,y)\in w} |I_l(x,y) - I_r(x-d,y)| \qquad \textbf{(1)}$$

Winner takes all method is used to select the best correspondence between the stereo image pixels. Interpolation technique is implemented to calculate the disparity at the non-edge pixels. To get a clean disparity, weighted least square smoothing filter is used to rectify the obtained disparity image. Disparity for a calibrated stereo system is given by the equation 2

$$D = \frac{b * f}{z} \qquad \textbf{(2)}$$

where

D- Depth of the object in pixels
b- distance between the two cameras
f - focal length of the lens
z- distance of object from the user

For the prototype disparity is 23 pixels for any object whose distance is greater than 7 meters and disparity is 100 pixels for any objects whose distance is less than 1.7 meters from the user. Hence the gray scale in disparity map is such that object with disparity more than 100 pixels are marked as white or pixel intensity 255 , objects with disparity less than 23 pixels is marked as black or pixel intensity 0 and for rest pixels linear relation between disparity and gray scale 1-254 is used. Rectified stereo images is as shown in the figure 5

Figure 5: Rectified stereo image captured by the system

Disparity calculated in stored in images. This disparity is as shown in figure 6.

Figure 6: Disparity map of captured images

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III. OBSTACLE DETETION AND AVOIDANCE ALGORITHM

Obstacle detection and avoidance algorithm detects obstacles in front the user, calculates the path free of obstacles and generates a vibration pattern that can help user to navigate. The algorithm works on segmentation of disparity map. Disparity map is segmented into four sections as shown in the figure 7

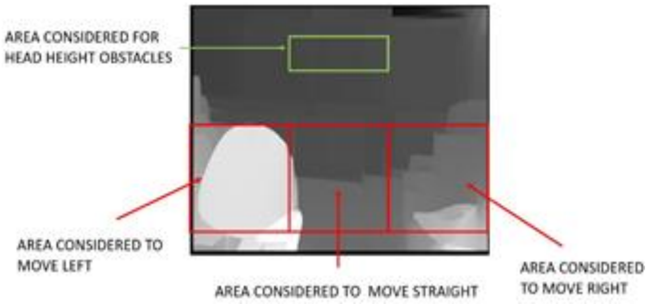

Figure 7: Segmented areas of disparity image

Experiments have shown that any head height obstacle at a distance of 2 meters or less gets mapped in the area marked as green and obstacles in distance of 1.7 meters to 7 meters gets mapped in reed area of disparity map as shown in figure 7. The algorithm to detect head height obstacle is as given in table 2

Table 2 : Head height obstacle algorithm

Algorithm 1 Head height obstacle detection algorithm	
Input: Disparity image	
Output : Auditory feedback	
1	Extract the area 20:40 rows and 161:300 columns of the disparity image.
2	Calculate the mode of the extracted area
3	**if** mode is greater than 100 **then**
4	Auditory feedback altering user that a head height obstacle is present in his current path

To detect obstacles in the path of the user, we consider the three red areas of the disparity map. We calculate the mode of each extracted red area. Mode of extracted area gives the information about the pixel intensity which appears maximum number of times in the given area. The extracted area which has the minimum pixel intensity is the area where obstacle is the farthest. Based on this information the vibration pattern is generated. The obstacle detection and avoidance algorithm and the vibration pattern is as given in table 3.

Table 3: Algorithm for obstacle detection and avoidance

Algorithm 2 Obstacle Detection and avoidance algorithm	
Input: Disparity image	
Output : Vibrotactile and auditory feedback	
1	Extract three areas from the disparity map
2	Calculate the mode of each extracted area
3	Find the position of minimum mode value of the three mode value
4	Find the minimum mode value of three mode value
5	**if** minimum mode is greater than 130 **then** Auditory feedback alerting user that there is no free path in front him
6	**else if** position = left red area then Left vibrators will start vibrating indicating the user has to move left.
7	**else if** position = central red area **then** No vibration feedback. User can move in the current direction.
8	**else if** position =right red area **then** Right vibrators will start vibrating indicating the user has to move right

The intensity of the vibration indicates the distance of the obstacle from the user. The table 4 shows relation between intensity of vibration and relative distance of the obstacle from the user.

Table 4: Relation between distance and vibration intensity

Distance	Duty cycle
Obstacle <= 1.7m	100%
Obstacle between 1.7m and 3.7m	75%
Obstacle between 3.7m and 5.7m	25%
Obstacle > 6m	0%
No free path	All Vibrators at 100%

IV. EXPERIMENTS AND RESULTS

A performance analysis of the prototype can be divided into three categories:

1. time required to train the user to understand the vibration pattern.
2. Average time required for user to cover a fixed distance with different number of obstacles.
3. Accuracy of obstacle detection and avoidance.

The prototype was tested on 5 blind folded people and 50 visually impaired users. The age ranged between 15 and 50. Distribution of the sample space is as shown in figure 8.

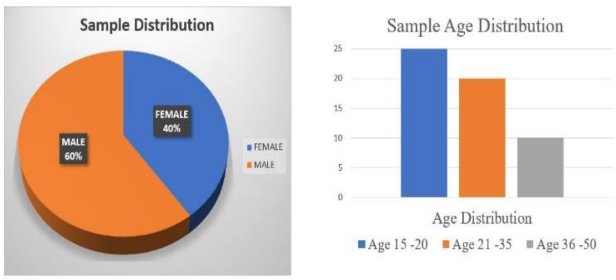

Figure 8 : Sample Distribution as per age and gender

All the test were done outdoor, this consisted of navigating through cluttered area.

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In training session, the users were asked to wear the prototype around their waist. First part of training included giving random vibration patterns and the user should respond accordingly. the user was then asked to walk on a road of length 30 meters and width 15 feet. Average time of navigation, accuracy of obstacle detection and avoidance and percentage of false detection of obstacles were calculated under three different situations:

1. no obstacle in front of the user.
2. three obstacles in front of the user.
3. 5 obstacles in front of the user.

All the obstacles in the experiment were stationary The arrangement of obstacles on the road are as shown in figure 9.

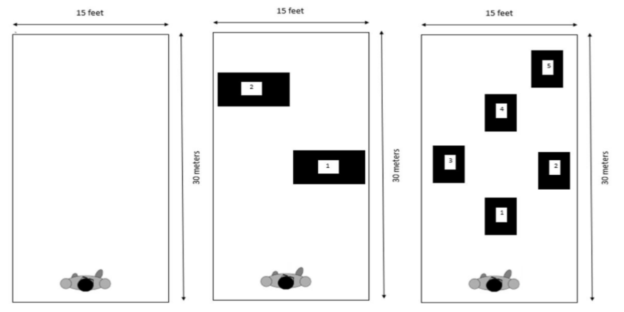

Figure 9: Arrangement of obstacles for validaion of the device

Following table shows the results obtained during the validation session.

Table 5 : Percentage accuracy of obstacle detection and average speed of commute

Age group	Male users	Female users	Average speed(m/s)	Accuracy
15-20	5	10	0.62	95.60%
21-35	15	7	0.6	95.00%
36-50	10	3	0.63	95.40%

The main result of our test is false detection of obstacles was close to 99.3%.Average time required for training the user was 30 minutes. Accuracy of obstacle detection and avoidance was 95.2%. The Average time required for the user to commute in all three situations varied between 0.6 m/sec to 0.93 m/sec. The weight of the prototype is 378 grams. Prototype can run for 8 hours on one complete charge of the li-ion battery.

V. CONCLUSION

In the present work computer vision based electronic mobility aid and obstacle detection and avoidance algorithm were proposed. The visually impaired users evaluated the prototype in real and controlled environments. Throughout the evaluation, subjects experienced reliable performance of the prototype. Due to two camera modules with larger field of view, user no longer needs to actively scan the area ahead of him/her. The user also received information about any head height obstacle if present. The proposed design has achieved obstacle detection accuracy of 95 % but further experimentation and validation of the prototype is required to increase the accuracy of obstacle detection and avoidance. The prototype also needs to be validated for performance in overcrowded areas like train stations.

FUTURE SCOPE

1. **Camera modules:** The future design of the prototype will be equipped with camera modules with larger field of view to increase scan area upto 150◦.
2. **Object Classification:** The prototype can be equipped to object classification technique that can give auditory feedback about the type of the obstacle in front of user.
3. **Stair Detection:** Stair detection would be a useful improvement to the design. Obstacle detection and avoidance algorithm along with stair detection algorithm can help user to commute with greater confidence in indoor environments.
4. **Global Navigation:** Another promising improvement consists of adding a localization module to the prototype. This would allow the user to enter a desired target location to the system and then have the prototype automatically guide user to that location

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REFERENCES

1. Global data on visually impairment. World Health Organization, 2010
2. L. Dunai, I. Lengua Lengua, I. Tortajada, and F. Brusola Simon, “Obstacle detectors for visually impaired people,” in International Conference on Optimization of Electrical and Electronic Equipment (OPTIM), pp. 809–816, May 2014
3. R. Jafri, S. A. Ali, H. R. Arabnia, and S. Fatima, “Computer vision-based object recognition for the visually impaired in an indoors environment: a survey,” The Visual Computer, vol. 30, no. 11, pp. 1197–1222, 2014
4. X. Lu and R. Manduchi, “Detection and localization of curbs and stairways using stereo vision,” in Proceedings of the 2005 IEEE International Conference on Robotics and Automation, pp. 4648–4654, April 2005.
5. S. Wang and H. Wang, “2d staircase detection using real AdaBoost,” in 2009 7th International Conference on Information, Communications and Signal Processing (ICICS), pp. 1–5, Dec 2009.
6. Y. H. Lee, T. S. Leung, and G. Medioni, “Real-time staircase detection from a wearable stereo system,” in Proceedings of the 21st International Conference on Pattern Recognition (ICPR2012), pp. 3770–3773, Nov 2012
7. “RGB-d image-based detection of stairs, pedestrian crosswalks and traffic signs,” Journal of Visual Communication and Image Representation, vol. 25, no. 2, pp. 263 – 272, 2014
8. “Stairs detection with odometry-aided traversal from a wearable RGB-d camera,” Computer Vision and Image Understanding, vol. 154, pp. 192 – 205, 2017
9. D. Jain, “Path-guided indoor navigation for the visually impaired using minimal building retrofitting,” in Proceedings of the 16th International ACM SIGACCESS Conference on Computers and Accessibility, pp. 225–232, 2014
10. Y. Zhou, G. Jiang, G. Xu, X. Wu, and L. Krundel, “Kinect depth image-based door detection for autonomous indoor navigation,” in The 23rd IEEE International Symposium on Robot and Human Interactive Communication, Scotland, UK, pp. 147–152, 2014

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Shrugal Varde, received his Bachelor of Engineering degree in Electronics from the University of Mumbai, India. He received his Master of Technology degree in Electronics from Veermata Jijabai Technological Institute (VJTI) of Mumbai, India. He is currently pursuing his Ph.D. degree in the Electronic Engineering Department at VJTI. His project incorporates the development of a computer vision based portable mobility aid for the visually impaired. He has authored and co-authored research papers published in several international journals and IEEE conference proceedings. His research interests include image processing, computer vision, machine learning, human-computer interactions and embedded systems

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