Electronic Travel Aid System for Visually Impaired People

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***Abstract*—Visually impaired people face unique challenges in their day to day life while navigating in unfamiliar public locations. Using a walking stick relies on trial and error, particularly in unfamiliar locations. Also from a walking stick the user can only identify obstacles which are touching the stick and cannot identify the obstacles which are above his waist height.**

Electronic Travel Aids (ETAs) are devices that use sensor technology to assist and improve the blind users mobility in terms of safety. In this context, we implement a system whose objective is to give blind users the ability to move around in unfamiliar environment, whether indoor or outdoor, through an interface specifically designed to cater the visual imperfections. This ETA system grants the user the ability to travel independently with an automated alerting system designed for emergencies. The obstacles are detected using image processing and distance sensing through IR sensors. A navigation system was developed to assist the user via web access.

Keywords: ***Electronic Travel Aids, GPS, Image Processing, Infra red, Visually Impaired***

I. Introduction

Vision impairments can result from a variety of causes, including congenital conditions, injuries, eye diseases, and brain trauma, or as the result of other conditions such as diabetes and multiple sclerosis. The navigation of visually impaired people is a difficult task due to the lack of extracted information for passing through obstacles and hazards in their pathway. The orientation and navigation in unknown environment seems impossible without any external assistance. Even if there are various technological solutions have been proposed, none of them clearly addresses a method for assisting daily activities of totally blind or visually impaired people. Within this context, a system that can provide robust and accurate localization of a visually impaired user in urban environments is a necessity. There is a wide range of navigation systems and tools available for visually impaired individuals. White canes and guiding dogs are the most popular [1]. White cane is the simplest, cheapest and the most popular navigation aid. However, it does not provide all the required information such as the speed of an object, volume and distances for obstacles, which are normally gathered by eyes and are necessary for the perception and the control of locomotion during navigation [2].

With the advancement of digital world, the research efforts are being directed to produce improved navigation aid systems, in which video cameras are used as vision sensors. The obstacle will be detected using various image processing techniques such as pre-processing, segmentation, adaptive threshold, and piece wise linear approach. For outdoor navigation environment a GPS could be used. Coordinates of various locations will be stored and the place would be notified to the blind person when he reaches there through a voice circuit. This system is using new technologies to improve the mobility and focuses on obstacle detection, and finding location in order to enhance navigation facilities for visually impaired people.

II. Related Work

The recent researches on wearable navigation systems for blind persons have been focused on developing devices that fall into the categories Electronic Orientation Aids (EOAs), Position Locator Devices (PLDs) and ETAs. One of such a solution would be to implement a simple navigation device to aid the blind person through audio assistance by embedding a GPS module with the proposed device [3]. This device would announce the directions to the user until the given target coordinates are reached. Monitoring devices have been developed with wireless cameras that convey the real-time video and audio streams to a monitoring station with assisting agent that handles any emergencies associated with blind personnel [1], [2]. In [4], a navigation belt was implemented with eight ultrasonic range sensors placed in different angles to detect obstacles using an obstacle avoidance algorithm. A single recurring beep guides the user to avoid obstacles. A similar approach to a white cane has been suggested in [7], in which the cane is attached with a device with wheels and a steering mechanism embedded with ultrasonic sensors to avoid and reroute when an obstacle is detected. When designing the proposed system of this research, efficiency, accuracy and practicability of above techniques were considered.

III. Design and System Implementation

The system consists of mainly three parts. Camera module and sensor network, Audio acknowledgment system and Navigation system.

A. Camera Module and Sensor Network

The main part of the system is a camera module with a related sensor network for recognizing an object which lies on his or her way. The distance for detected object and the speed of the dynamic objects are being calculated by this part. Image processing technique is the main object identification method in this device and it is being used for the continuous

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object processing along the blind persons way and then users are receiving audio acknowledgments if the identified objects are below the pre-defined range.

The camera module consists of two Raspberry Pi Rev 1.3 cameras which are capable of capturing 1080p30, 720p60 and $640 \times 480p60/90$ video and 2592×1944 pixel resolution for static images [8]. Raspberry Pi 3-model B v1.2 micro-controller which is running on Raspbian operating system board is used for image processing. The sensor array consist of three SHARP GP2Y0A710K0F infrared distance measurement sensors which works on the principle of optical triangulation [6].

B. Audio Acknowledgment System

This system is used to supply voice commands related to objects or obstacles which are detected by the sensor array or image processing to the user of the ETA. The information regarding the current location of the user or the destinations that the user requires to reach are notified by the audio acknowledgments using the eSpeak library.

C. Navigation System

GY-NEO6MV2 GPS Module is used to get the current GPS coordinates of the user and Arduino Pro Mini ATmega328 micro-controller has been used to serially communicate with raspberry pi module and obtained coordinates are sent to Google MAP API to find out the current location. The nearby places that user needs to reach can be found using Google place API. The directions for a selected place can be found using the Google direction API. The complete system architecture is illustrated in Fig. 1.

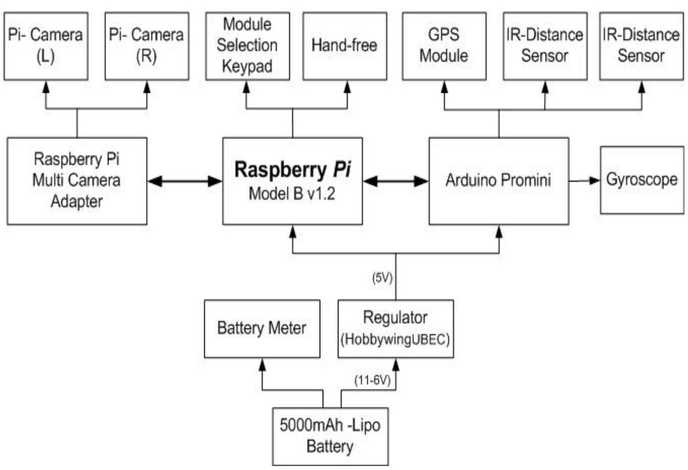

Fig. 1. The proposed system architecture of the ETA

IV. Detecting Objects

Human retina is just a flat screen inside the eye. An image is the equivalent of visual input to the brain from both eyes. The brain takes both image inputs together and uses the slight differences between them to create a perception of depth for objects.

In this system the distance for the objects are calculated by comparing disparity of the two images taken by two front cameras as shown in Fig. 2.

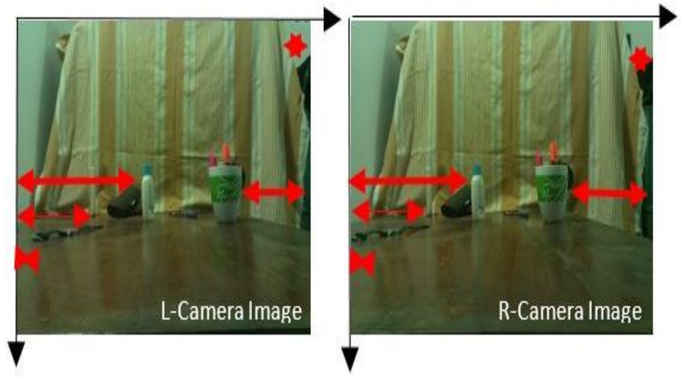

Fig. 2. Disparity of images taken from two cameras

The distance of the particular object can be calculated considering the point in which the epipolar plane cuts through image planes. Forming an epipolar line in each plane would lead to finding the object distance from the equations and Fig. 3 given below.

$$Z\tan(\theta_1) + Z\tan(\theta_2) = X_0 \tag{1}$$

$$Z(\tan(\theta_1 + \theta_2)) = X_0 \tag{2}$$

$$Z = \frac{X_0}{\tan(\theta_1) + \tan(\theta_2)} \tag{3}$$

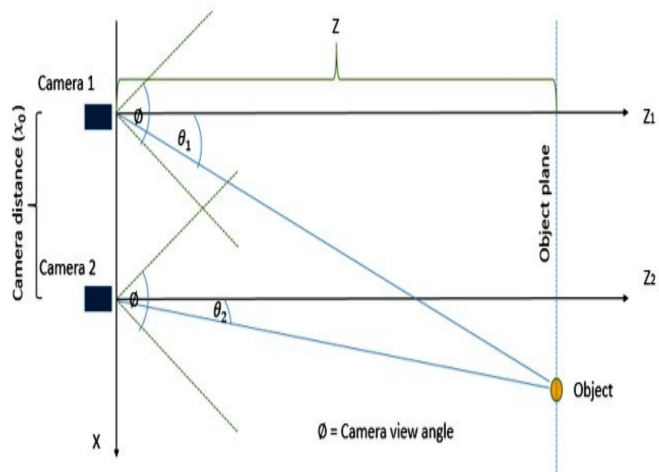

Fig. 3. Location of the object with respect to two cameras

In our case, camera view angle ϕ is equal to 55°. $\tan(\theta_1)$ and $\tan(\theta_2)$ has to be determined maintaining the disparity of two camera images in the same epipolar line.

A. Calculating Disparity

Finding the same points of two images are calculated using the disparity of images. Image sampling, quantization and window matching are used for finding disparity. In Fig 4, for each pixel in the left camera image is compared with each pixel in the right camera image.

This is achieved by comparing a selected pixel window with several windows on the same epipolar line in the right image Using Sum of Squared Differences, Scale Invariant Feature Transform (SIFT) or Speeded Up Robust Features (SURF) algorithms.

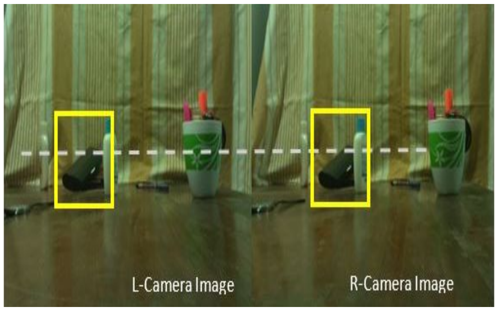

Fig. 4. Identifying the same points in two different camera images

B. Calculating $\tan(\theta_1)$ *and* $\tan(\theta_2)$

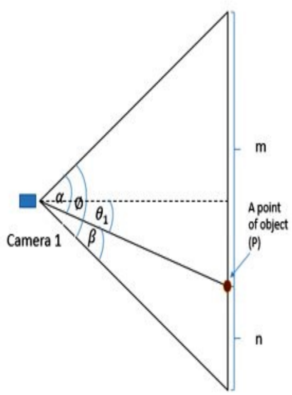

Fig. 5. Angle measurements between the cameras and the object

Consider the camera 1 in Fig. 5;

$$\frac{m}{n} = \frac{\text{Number of pixels from y-axis to P-point on L-side}}{\text{Number of pixels from y-axis to P-point on R-side}} \tag{4}$$

According to the sin law, we can prove that;

$$\frac{sin\alpha}{m} = \frac{sin\beta}{n} \tag{5}$$

Therefore,

$$\alpha = 55^\circ - \beta$$
$$m \sin\beta = n \sin(55^\circ - \beta)$$
$$m \sin\beta = n[\sin 55^\circ . \cos\beta - cos55^\circ . \sin\beta]$$

$$\tan\beta = \frac{n \sin 55^\circ}{m + n \cos 55^\circ} \tag{6}$$

$$\beta = \frac{55^\circ}{2 + \theta_1} \tag{7}$$

$$\tan\theta_1 = \tan(\beta - 55^\circ/2) = \frac{\tan\beta - \tan 55^\circ/2}{1 + \tan\beta . \tan 55^\circ/2} \tag{8}$$

$\tan\theta_1$ can be determined by substituting $\tan\beta$ value to the above equation. Similarly, $\tan\theta_2$ can be computed.

Time taken for image processing by the camera is very high at the beginning due to high processing time (around 7 to 8 minutes). This can be avoided by working the camera in its video mode. Therefore it processes the real time photographs taken by the camera and shuttering delay and processing delay can be reduced to 5 to 10 seconds. Resolution reduction and threading (Raspberry pi has two cores [8]. So two threads were used) were carried out to reduce the processing time further.

C. Image Processing Process

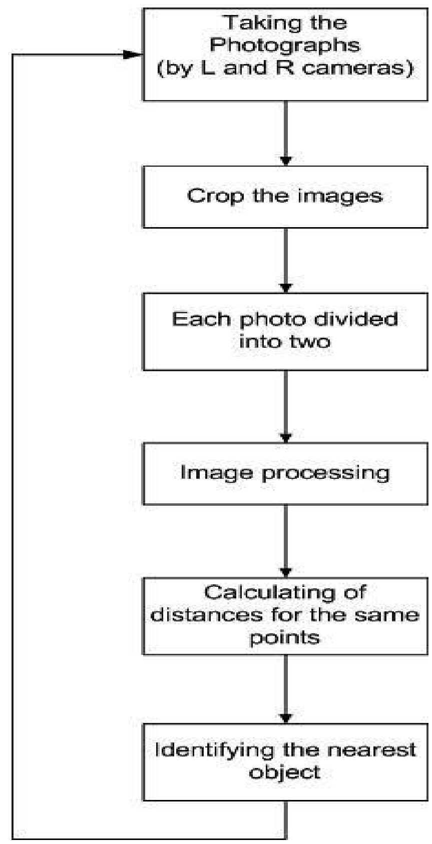

Fig. 6. Flow diagram of the proposed image processing process

The diagram in Fig. 6 shows the main steps and the working methodology. At first, the cameras take two photographs and they are cropped by 50% due to the larger area in the photograph which results in reduced time for image to process. Therefore the images are cropped to a 50% scale. Each cropped image is sent to thread 0 and thread 1 to process the images separately.

Thread 0 and 1 are the independent parallel processing threads, which are generated to calculate distances for the same points. The images are cropped and scale downed. The cropped images have to be processed in order to calculate distances of the objects. In this process we have used parallel processing to achieve a high calculating speed and a low time consumption to process the image.

Therefore, top half of the left camera image and top half of the right camera image are sent to thread 0 for processing while bottom halves of left and right images are sent to thread 1. The same points of the pictures are identified by the generated software algorithm, SIFT algorithm in OpenCV library and the differences between the same points can be calculated by Disparity processed where parallel processing is used [9]. Therefore disparity concept is capable to calculate the real distance for the actual object from the cameras (user). Though the real distances are calculated, all the readings are not yet acknowledged to the user. The distances between the user and the pre-defined limit will be acknowledge to the user. The final processed image as shown in Fig. 7 and voice commands are processed within 5 to 10 seconds.

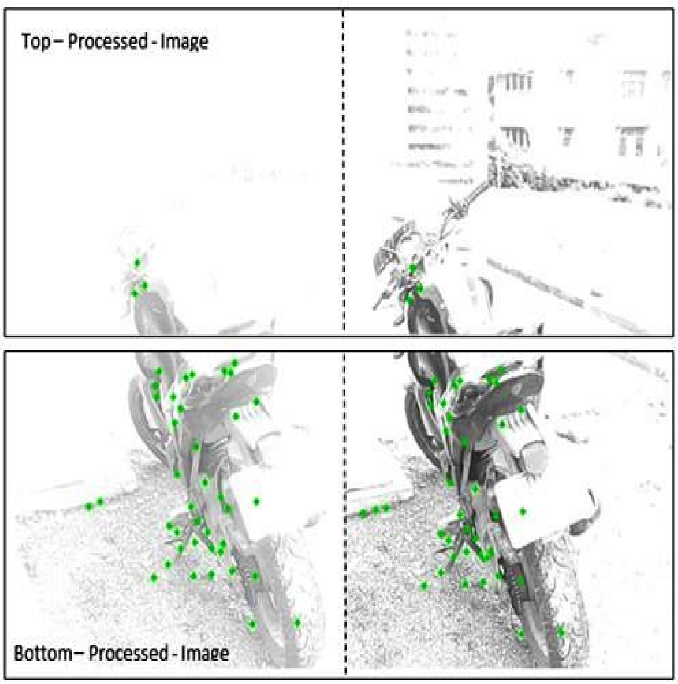

Fig. 7. Final version of the processed image

V. Navigation System

A. Extracting Current Position

When the user requires the current position, Geo coordinates of the current location is found from the GPS system and then it is forwarded to the Reverse geocoding process at the Google Maps Geocoding API. The XML data object from the API is processed to get the formatted address correspond to the current position and it is read out from the audio acknowledgment system.

In order to accomplish this function, a https request was formulated to extract the XML object for the current location via web services. In this request several variables are sent through the request. They are latitude, longitude, requesting address and a key used for the API authorization. This process is illustrated in Fig. 8.

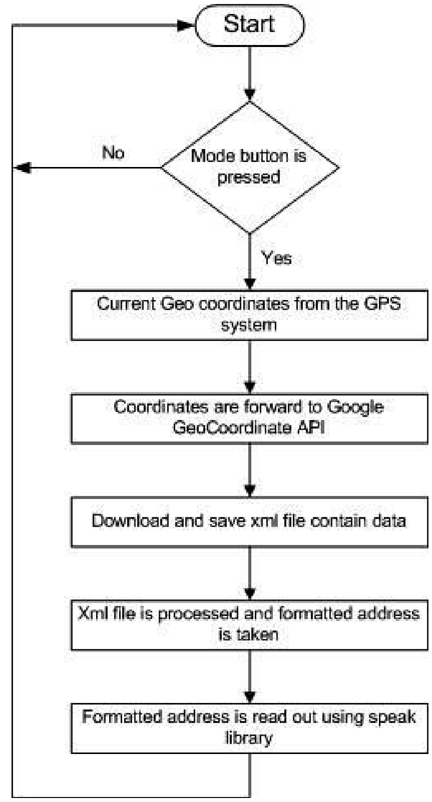

Fig. 8. Flow diagram of the process for extracting the current Location

When the user requires the current position, Geo coordinates of the current location is found from the GPS system and then it is forwarded to the Reverse geocoding process at the Google Maps Geocoding API. The XML data object from the API is processed to get the formatted address correspond to the current position and it is read out from the audio acknowledgment system.

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B. User Directing Service

When the user needs the directions for a location around the current position, Geo coordinates of the current location is found from the GPS system and then it is forwarded to the Google Places API. This Web Service allows to query the place information on a variety of categories, such as: establishments, prominent points of interest, geographic locations, and more [5].

In this process, following sample locations such as bus station, food, doctor, pharmacy, and train station were used. Then the user can select the required option from the buttons and request is made through web service. Then XML data object from the API is processed to get the relevant data correspond to the option and it is read out from the audio acknowledgment system.

Then from these results user can select a destination and using the Google Maps Directions API which is a service that calculates directions between locations using an HTTP request is used to get the Directions and distances between the current location and the destination. The XML output from the above request is processed and the HTML instructions are read out through the sound acknowledge system.

C. Emergency Alerting Service

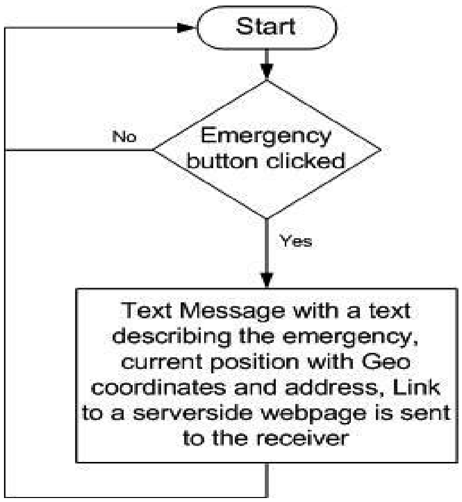

Fig. 9. Flow diagram of the emergency alert system

In case of an emergency, user can alert the situation via a text message to a predefined authority. Hardware implementation includes an emergency button in the keypad. When the user click this button, a text message is sent over the SMS service from a 3G dongle which is connected to the Raspberry Pi. These emergency messages contain the current position with geo coordinates and the address and a link to a server site which contain the path of the user and current snaps from the camera. Implementation uses the GAMMU library in the Raspbian OS.

D. Path Tracking

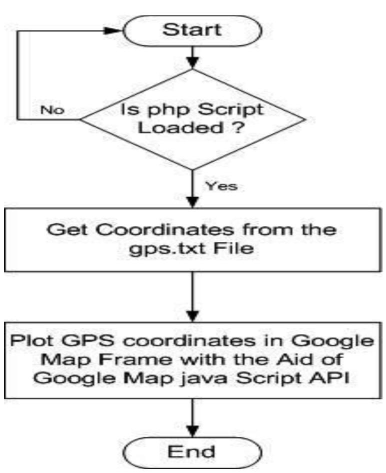

Fig. 10. Flow Diagram for Path Tracking

A PHP site is hosted in the apache server for tracking the path of the user. At a time interval of one minute, geo coordinates from the GPS system are saved in a text file. A PHP script is written to retrieve the coordinates from the text file and they are then mapped in a Google map using Google maps JavaScript API. Fig. 10 shows the process of tracking the user. Moreover, Fig. 11 illustrate a sample tracking trial.

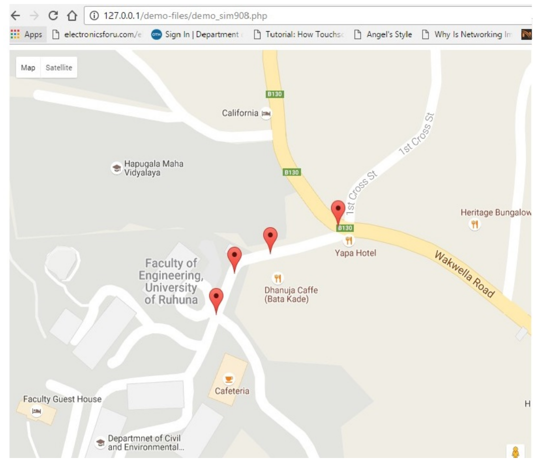

Fig. 11. User tracking website

VI. Experimental Results

The developed system should be capable of delivering the exact or high accuracy distance measurements and audio acknowledgments related to obstacles or moving objects.

Obstacles with different heights were checked with the system for their detection using image processing and IR sensor array for different horizontal distances. The objective is to identify the relationship between the actual distance and the distance response given through the audio circuitry in the prototype system. An object with 30 cm of height was used as the obstacle. Measurements are tabulated in TABLE I.

TABLE I
Error Percentage of the Distance Response for an Object of 30cm Height

Actual Distance to the Object (cm)	System Suggested Distance (cm)	Absolute Error Percentage (%)
45	46.71	3.80
85	87.89	3.40
125	122.05	2.36
165	169.21	2.55
205	201.47	1.72
245	239.64	2.19
285	291.9	2.42
325	319.22	1.78

In the next stage an object with a height of 90 cm was used as the obstacle to get the distance values that the audio acknowledgment system acknowledged to the user for the same distance instances were tested. These measured values are indicated in TABLE II.

The results of a test carried out for an object with a height of 150 cm are tabulated in TABLE III.

TABLE II
ERROR PERCENTAGE OF THE DISTANCE RESPONSE FOR AN OBJECT OF 90CM HEIGHT

Actual Distance to the Object (cm)	System Suggested Distance (cm)	Absolute Error Percentage (%)
45	45.9	2.00
85	83.82	1.39
125	124.15	0.68
165	163.33	1.01
205	208.43	1.67
245	249.16	1.70
285	291.64	2.33
325	318.8	1.91

TABLE III
ERROR PERCENTAGE OF THE DISTANCE RESPONSE FOR AN OBJECT OF 150CM HEIGHT

Actual Distance to the Object (cm)	System Suggested Distance (cm)	Absolute Error Percentage (%)
45	47.45	5.44
85	88.11	3.66
125	128.74	2.99
165	169.87	2.95
205	200.25	2.32
245	245.89	0.36
285	290.75	2.02
325	332.72	2.38

The Fig 12 shows the comparison of the distance response for three objects of heights 30 cm, 90 cm and 150 cm. According to Fig 12, error percentage converge towards the 2.00% error when the distance is increasing.

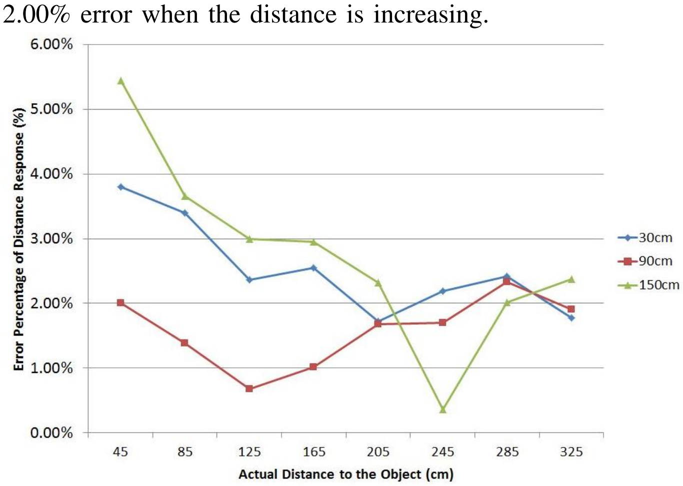

Fig. 12. Comparison of the distance responses for variable height obstacles

Therefore, the results suggest that the error is minimal when the distance to the object reaches around 3 m where in this case is acceptable to identify the obstacles to avoid them by a blind person.

VII. CONCLUSIONS

Proposed concept in this paper is a novel approach for providing navigation for visually impaired people. The advantage of this system lies in the fact that it can provide multi-functional solutions to blind people around the world. The proposed system is a combination of various working units which collectively produce a real-time system that detects obstacles while making navigation of the blind people more safe and secure.

The implemented system uses two cameras and two IR sensors for obstacle detection. Camera output has a clear identification of the environment and Infrared sensors with analog outputs have excellent repeat sensing accuracy. It is possible to ignore immediate background objects, even at long sensing distances because switching hysteresis is relatively low.

The implemented system was planned to introduce GPS for locating the position of the user and navigate him to the selected destination with directions. Location of the user is tracked using GPS system and the coordinates are integrated with Google Maps API to get the address of the current location. Another implemented feature is to give directions to a selected place around the current location of the user. The important feature in the navigation system is the alerting a third party about an emergency for the user. So this will send an SMS to the predefined third party (relation/police station) conveying the emergency.

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