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Darshan: Electronics Guidance For The Navigation Of Visually Impaired Person

Marut Tripathi^{#1}, Manish Kumar^{#1}, Vivek Kumar^{#1}, Warsha Kandlikar^{#2}

[#]National Institute of Electronics and Information Technology, Aurangabad

¹M.Tech Students

²Scientist C

Abstract— This paper presents Darshan a Navigation System for blind people to navigate safely and quickly, in the system an obstacle detection and recognition is done through ultrasonic sensors and USB camera. The proposed system detects the obstacles up to 300 cm via ultrasonic sensors and sends feedback in the form of beep sound via earphone to inform the person about the obstacle. USB webcam is connected with Raspberry Pi Embedded board which captures the image of the obstacle, which is used for finding the properties of the obstacle (Human Being). Human presence is identified with the help of human face detection algorithm written in Open CV. The constraints coming while running the algorithm on Embedded System are limited memory and processing time and speed to achieve the real time image processing requirements. The algorithm is implemented in Open CV, which runs on Debian based Linux environment.

Keywords— Navigation System; Visual Impairment; Navigation Aid; Ultrasonic Range Sensor; Embedded System; Human Being Detection

I. INTRODUCTION

The work we present in this paper is based on the use of new technologies to improve visually impair people mobility. The focus of this paper is navigation aid for the blind and disabled. Disability is a curse to a person especially if the person is blind. According to survey conducted in 2012 by World Health Organization on disability, there were 285 million visually impaired people in the world, of which 246 million had low vision and 39 million were blind worldwide [1]. Commuting in a crowded environment for the blind is much more challenging than for a normal person. The work we present in this paper is based on the use of new technologies to improve visually impair people mobility. Our research focuses on obstacle detection in order to reduce navigation difficulties for visually impaired people. Moving through an unknown environment becomes a real challenge when we can't rely on our own eyes [2]. Since dynamic obstacles usually produce noise while moving, blind people develop their sense of hearing to localize them [3]. However they are reduced to their sense of touch when the matter is to determine where an inanimate object exactly is. The common way for navigating of visionless person is using a white cane or

walking cane. The walking cane is a simple and purely mechanical device dedicated to detect static obstacles on the ground, uneven surfaces, holes and steps via simple tactile-force feedback. This device is light, portable, but range limited to its own size and it is not usable for dynamic obstacles detection neither than obstacles not located on the floor.

Another option that provides the best travel aid for the blind is the guide dogs. Based on the symbiosis between the disabled owner and his dog, the training and the relationship to the animal are the keys to success. The dog is able to detect and analyse complex situations: cross walks, stairs, potential danger, know paths and more. Most of the information is passed through tactile feedback by the handle fixed on the animal. The user is able to feel the attitude of his dog, analyse the situation and also give him appropriate orders. But guide dogs are still far from being affordable, around the price of a nice car, and their average working time is limited, around 7 years [4].

Due to the development of modern technology, many different types of navigational aids are now available to assist the

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blinds [5]. They are commonly known as Electronic Travel Aids.

Some of these aids are Sonic Pathfinder [6], Mowat-Sensor [7] and Guide-Cane [8], but having very narrow directivity. However, Sonic-Guide [9], NavBelt [10] and other ETA devices [11, 12] are having wide directivity and are able to search several obstacles at the same time. These devices are all based on producing beams of ultrasonic sound or laser light. In such a system, the device receives reflected waves, and produces either an audio or vibration in response to nearby objects, but its market acceptance is rather low as useful information obtainable from them are not significantly more than that from the long cane and responses received from them are not user friendly. So recent research efforts are being directed to produce new navigational system in which digital video camera is used as vision sensor. Some of these ETA devices are vOICe [13], NAVI [14], SVETA [15] and CASBLIP [16] and Electronic Travel Aid [17].

In vOICe, the image is captured using single video camera mounted on a headgear and the captured image is scanned from left to right direction for sound generation. The sound is generated by altering the top of the image into high frequency tones and the bottom portion into low frequency tones. The loudness of sound depends on the brightness of the pixels. Similar work has been carried out in NAVI where the captured image is resized to 32x32 and the gray scale of the image is reduced to 4 levels. The image is differentiated into foreground and background using image processing techniques. The foreground and background are assigned with high and low intensity values respectively. Then the processed image is converted into stereo sound where the amplitude of the sound is directly proportional to intensity of image pixels, and the frequency of sound is inversely proportional to vertical orientation of pixels. In SVETA, an improved area based stereo matching is performed over the transformed images to compute dense disparity image. Low texture filter and left/right consistency check are carried out to remove the noises and to highlight the obstacles. To map the disparity image to stereo musical sound, sonification procedure is used. In CASBLIP, the object is detected through sensors and stereo vision. In addition to this, orientation is computed using GPS system. This system is embedded on the Field Programmable Gate Array (FPGA).

The most important factors, which enable blind users to accept these devices readily, are portability, low cost, and

above all simplicity of controls. Hence, ETA device should be small in size and lightweight for portability. Since a blind person is not able to see the display panel or control buttons, hence the device should be easily controllable. Moreover, the ETA device should be of low-cost so as to be affordable by a common man.

Considering all these requirements, Raspberry Pi is used as processing unit in the system. The processing of the ETA device is performed on this embedded system. It controls all the modules which are used to navigate the user. The system we have designed consists in sensing the surrounding obstacle via sonar sensors and sending audio feedback (beep sound) to the user of the position of the closest obstacles in range. This means that the user should use it, after a training period, without any conscious effort, as an extension of its own body functions. Since there's reluctance from the visually impaired community toward new technologies, we design our system as a complement of the traditional white cane. It will focus on detecting obstacle at shoulder high and on letting the user perfectly hand free.

II. PROPOSED ELECTRONIC TRAVEL AID

The system is based on Raspberry Pi a small computer board, a small (4" x 4") embedded board having ARM 11 processor [18]. The ultrasonic sensors are connected with the board. It feeds the distance data to the Raspberry Pi. A USB webcam is connected with Raspberry Pi for capturing the field of view of the person, which is used for locating a human being. A headphone is connected with Raspberry Pi to get the audio feedback (beep sound) of the obstacle distance and presence of human being. The Raspberry Pi board is powered by 5V, 2A DC adapter. The algorithms are implemented in C using Open CV library files, which runs on Debian based Linux environment.

Figure 1 depicts the proposed system for ETA. For better field of view and result, USB webcam and ultrasonic sensors are placed on the user's belt. Three easy control switches are provided to control the ultrasound based distance measurement system, human detection system and motion detection system respectively. The Raspberry Pi board is kept in the bag which will be held on the waist of the user. The user has to operate the system manually and he/she will get the auditory feedback till the switches are pressed.

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Figure 1. Proposed Navigation System

III. OBSTACLE DETECTION AND DISTANCE CALCULATION

A. OBSTACLE DETECTION:

Ultrasonic sensors are used for obstacle detection and calculation of its adaptive distance from the visually impaired person. Ultrasonic sensors are used in pair as transceivers. One device which emits sound waves is called as transmitter and other who receives echo is known as receiver. These sensors work on a principle similar to radar or sonar which detects the object with the help of echoes from sound waves. An algorithm is implemented in C-language on Raspberry Pi. The time interval between sending the signal and receiving the echo is calculated to determine the distance to an object. As these sensors use sound waves rather than light for object detection, so can be comfortably used in ambient outdoor application.

Input Requirement:

Working Voltage: 5 V (DC)

Working Current: 15mA

Input trigger signal: 10us impulse TTL

Output Signals:

Echo signal: PWM signal. Time required for sound signal to travel twice between source and obstacle

Range: 4 meters.

B. DISTANCE CALCULATION:

For distance calculation following equation is used:

$$D = [(EPWHT) * (SV)/2] \dots (1)$$

Where,

D = Distance in cm

EPWHT = Echo pulse width high time

SV = Sound velocity in cm/s

Before concluding the obstacle distance from the subject, repeated information sampling and averaging is performed. As ambient light conditions do not affect ultrasonic sensors, object detection and distance calculation can be performed accurately. Finally, object distance is calculated and accordingly the feedback (beep sound) is provided to the user.

The performance of the ultrasound based measurement system has been evaluated by using the experimental setup. The system is calibrated by placing an obstacle at a measured distance in front of the sensor. The calibrated distance (d_{cal}) is measured by using first order interpolation and the mapping between the pulse count and the distance. This calibrated distance is compared with distance computed from the velocity of sound (d_v). From the experimental data it is found that for distances 15cm to 150 cm, there is no error between the two distances (d_{cal} and d_v). However, after a distance of 150cm, due to one to many mapping, there is error in the calibrated distance. In order to reduce this error, average of three consecutive calibrated distances has been considered. The system detects the obstacles up to 300 cm. The system is also inert to background noises since the ultrasound frequency (40 kHz) is well beyond the audible frequency range (20 Hz – 20 kHz).

IV. DETECTION OF HUMAN BEING

The detection of human presence is carried out by detecting the human face. However there are situations, when the face is not present in the field of view of the camera in spite of the presence of a human in front of the visually impaired person. Such type of presence of human being may be asserted by detecting cloth and human skin. To detect the presence of human, if cloth is found in the vicinity of human skin, and face is not detected (if Side faces), then it will be considered as human.

A. Face Detection

Object Detection using Haar feature-based cascade classifiers is an effective object detection method proposed by Paul Viola

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and Michael Jones in their paper, “Rapid Object Detection using a Boosted Cascade of Simple Features” in 2001. It is a machine learning based approach where a cascade function is trained from a lot of positive and negative images. It is then used to detect objects in other images. Here we will work with face detection. Initially, the algorithm needs a lot of positive images (images of faces) and negative images (images without faces) to train the classifier. Then we need to extract features from it. For this, haar features shown in below image are used. They are just like our convolutional kernel. Each feature is a single value obtained by subtracting sum of pixels under white rectangle from sum of pixels under black rectangle.

Now all possible sizes and locations of each kernel is used to calculate plenty of features. (Just imagine how much computation it needs? Even a 24x24 window results over 160000 features).

For each feature calculation, we need to find sum of pixels under white and black rectangles. To solve this, they introduced the integral images. It simplifies calculation of sum of pixels, how large may be the number of pixels, to an operation involving just four pixels. Nice, isn't it? It makes things super-fast.

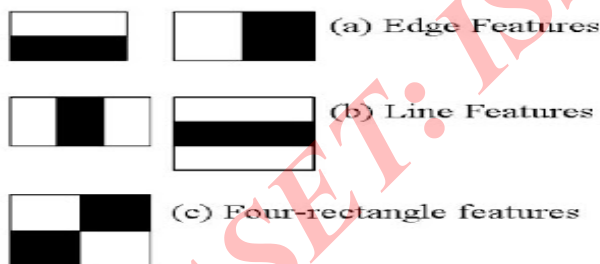


Figure 2. Haar Cascade

But among all these features we calculated, most of them are irrelevant. For example, consider the image below. Top row shows two good features. The first feature selected seems to focus on the property that the region of the eyes is often darker than the region of the nose and cheeks. The second feature selected relies on the property that the eyes are darker than the bridge of the nose. But the same windows applying on cheeks or any other place is irrelevant. So how do we select the best features out of 160000+ features? It is achieved by **Adaboost**.



Figure 3. Eye Detection using Haar Cascade

For this, we apply each and every feature on all the training images. For each feature, it finds the best threshold which will classify the faces to positive and negative. But obviously, there will be errors or misclassifications. We select the features with minimum error rate, which means they are the features that best classifies the face and non-face images. (The process is not as simple as this. Each image is given an equal weight in the beginning. After each classification, weights of misclassified images are increased. Then again same process is done. New error rates are calculated. Also new weights. The process is continued until required accuracy or error rate is achieved or required number of features are found).

Below given figure is Sample snapshot being taken by executing the programme.

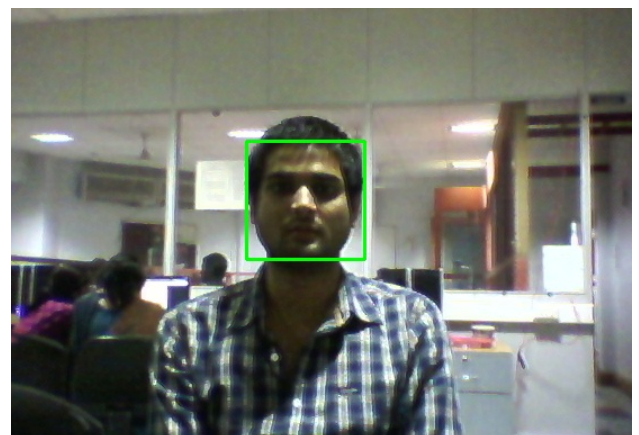


Figure 4. Face Detection using Haar Cascade

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B. Detection of Cloth

The image is subdivided into 48 non-overlapping sub images of size 20x20 pixels and these sub images are processed by using 'Haar' wavelet decomposition at level 1. The energy values of the approximate (eA) and detail coefficients (eH for horizontal, eV for vertical and eD for diagonal) coefficients are computed for each sub image. These energy values are considered as features to classify cloth texture.

C. Detection of Human

For human detection the HOG person detector uses a sliding detection window which is moved around the image. At each position of the detector window, a HOG descriptor is computed for the detection window. This descriptor is then shown to the trained SVM, which classifies it as either "person" or "not a person".

To recognize persons at different scales, the image is subsampled to multiple sizes. Each of these subsampled images is searched. The programme sample is being tested as below snapshot .



Figure 6. Human Detection using HOG Descriptor

V. DESCRIPTION OF TOOLS

In this section the tools and methodology to implement the proposed system and evaluate face detection using Open CV are detailed.

A. OPENCV

Open CV (Open Source Computer Vision Library) is a library of programming functions mainly aimed at real time computer vision, developed by Intel and now supported by Willow Garage. It is free for use under the open source BSD license. The library is cross-platform. It focuses mainly on real-time image processing.



Figure 6: Object Detection Pattern using Open CV

The library was originally written in C and this C interface makes Open CV portable to some specific platforms such as digital signal processors. Wrappers for languages such as C#, Python, Ruby and Java (using Java CV) have been developed to encourage adoption by a wider audience [Zhang, 2008]. However, since version 2.0, Open CV includes both its traditional C interface as well as a new C++ interface. This new interface seeks to reduce the number of lines of code necessary to code up vision functionality as well as reduce common programming errors such as memory leaks (through automatic data allocation and de-allocation) that can arise when using Open CV in C as shown in figure 4. Most of the new developments and algorithms in Open CV are now developed in the C++ interface [Bradski & Kaebler, 2009]. Unfortunately, it is much more difficult to provide wrappers in other languages to C++ code as opposed to C code; therefore the other language wrappers are generally lacking some of the newer Open CV 2.0 features. A CUDA-based GPU interface has been in progress since September 2010.

B. EXTENSIBLE MARKUP LANGUAGE (XML)

It is a markup language that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable. It is defined in the XML1.0 Specification produced by the W3C, and several other related specifications all gratis open standards. The design goals of XML emphasize simplicity, generality,

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and usability over the Internet. It is a textual data format with strong support via Unicode for the languages of the world. Although the design of XML focuses on documents, it is widely used for the representation of arbitrary data structures, for example in web services. Many application programming interfaces (APIs) have been developed to aid software developers with processing XML data, and several schema systems exist to aid in the definition of XML-based languages. The steps for training a haar classifier and detecting an object can be divided into:

s
s
vec file
r

We have used the xml file for detection of Human.

C. PROCESSING SOFTWARE

The Processing language is a text programming language in C++ and it uses the Open CV library files for the image processing application specifically. Processing strives to achieve a balance between clarity and advanced features. The system facilitates teaching many computer graphics and interaction techniques including vector/raster drawing, image processing, color models, mouse and keyboard events, network communication, and object-oriented programming. Libraries easily extend Processing ability to generate sound, send/receive data in diverse formats.

D. Raspberry Pi

Raspberry Pi is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software.

The Raspberry Pi has a Broadcom BCM2835 system on a chip (SoC), which includes an ARM1176JZF-S 700 MHz processor, Video Core IV GPU, and has 512 MB of RAM. It does not include a built-in hard disk or solid-state drive, but it uses an SD card for booting and persistent storage.

The software consists of a standard programming language compiler and the boot loader that runs on the board.

Raspberry Pi can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microprocessor on the board is programmed using the Python or C programming language. Raspberry Pi projects can be stand-alone or they can communicate with software running on a computer.

The board as shown in figure 5 can be purchased preassembled; the software can be downloaded for free. The hardware reference designs (CAD files) are available under an open-source license.



Figure 7: Raspberry Pi Model B Board

VI. RESULTS AND DISCUSSION

In order to test the ETA device on the blind folded persons, a system prototype is developed as shown in Figure 5 where USB webcam and ultrasonic sensors are placed on the user's belt. Three easy control switches are provided to control the ultrasound based distance measurement system, human detection system and motion detection system respectively. The whole circuit and the Raspberry Pi board is carried by the user in the bag.

To evaluate the performance of the Electronic Travel Aid device, it is tested on trained and novice peoples in the laboratory environment. Three easy control switches are provided to manually operate the device. First switch is to find the obstacles in the path of the blind person and second one is used to find the human presence in field of view of the camera and the last switch is used to detect any movement in front of the person. The device provides auditory feedback to the user in response to the switch pressed. For example, if user presses the first button to find the obstacles on his/her path, device will produce the beep sound whose loudness will increase or decrease with respect to the obstacle distance. To easily

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operate the device and to understand the auditory feedback, a proper training is required.

A total of eight tests have been carried out in laboratory environment and outside on three blind folded persons in which two are trained subjects and one subject is novice. After blindfolding the person, he/she is asked to walk through the corridor where different type of obstacles has been placed within 10 meter range. During the experiment, user's walking motion is recorded in video camera. Time taken by the users (trained and novice) for successfully walking through the obstacles is measured and travel speed for each test has been calculated as depicted in Table I.

Table I. Experimentation results of Electronic Travel Aid

	User Type	Obstacles	Human Presence	Obstacle Cleared	Travel Speed (m/s)
Test 1	New User	4	No	4	0.35
Test 2	New User	5	No	4	0.30
Test 3	New User	6	Yes	5	0.40
Test 4	New User	3	Yes	3	0.45
Test 5	Trained User	6	No	5	0.60
Test 6	Trained User	5	Yes	5	0.65
Test 7	Trained User	5	Yes	5	0.63

It is apparent from the Table I that average speed of a trained and new users are 0.63 and 0.38 m/s respectively. In comparison with the traveling speed of the sighted people (1.3 m/s). The accuracy of the device in finding out obstacles is 92%. This result shows that training of the user is one of the important factors for gaining high traveling speed and also to increase user's confidence to choose optimal path.

VII. CONCLUSION

An electronic travel aid to navigate visually impaired persons has been proposed here. The aid has been tested in laboratory environment. Using this ETA device blind user can pass through the unknown environment independently. The major issues for the users to accept these aids are that they should be unobtrusive, easy to carry and for the convenience of the blind user, device is small and light weight. User needs to wear belt in which camera and sensor is mounted. The user has to carry Raspberry Pi Board and sensor unit of nearly 500 gm. This device can detect obstacles up to 300 cm and human presence within 120 cm. A portable ETA device has been developed taking into account the blind users' requirements and it fills the gap between these requirements and the presently available aids.

System has following advantages:

Advantages:

- Accurate detection of obstacles in front left and right direction
- Detection of waist level height to head level height obstacles
- Minimum physical interface
- Less training time
- Human being detection

Considering the expectations and requirements of the visually impaired and blind people, this system offers a low cost, reliable, portable, low power and robust solution for smooth navigation. Though the system is light weight, but hard wired with sensors and other components. Further wearable aspect of this system can be improved using wireless connectivity between the system components. This system is developed considering visually impaired and blind people in developing countries.

VIII. FUTURE WORK

In Future Such implementation can be done by improving certain system parameters of the system which are following:

- Detection of ground level obstacles
- Recognition of colors

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- Detection of Multiple Objects

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