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Development of a Smartphone-based Real Time Outdoor Navigational System for Visually Impaired People

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Abstract— **In this paper, we have given a practical solution for solving the problem of visually impaired people using a android based mobile platform. An application is created for detecting obstacles, ups & downs in front of the user. It also detects safe zone in pedestrian lane & gives audio feedback. Using techniques of hough transform and segmentation a real time outdoor navigational system is implemented at the least expenses. It detects line in real time video and make use of OpenCV library.**

Keywords— ***Image-Processing, Hough Transform, Segmentation, Visually Impaired, OpenCV***

I. INTRODUCTION

Blindness is a disease that limits a person's ability to navigate surroundings. Blindness means individuals with no usable vision or only the ability to perceive light. It is a common disease all around the world. According to WHO about 285 million [1] people are blind all over the world. In Bangladesh the number is about 7,50,000. Visually impaired people need help to find their way in unfamiliar places. Usually, they use cane for helping themselves. Though, a support cane gives physical stability it doesn't tell if there is an object or obstacle in front of the person carrying the cane. One of the most common problem for blind people is obstacle avoidance. Obstacles make it difficult for blind people to navigate surroundings. Obstacle avoidance deals with the objects and land in the current area around the individual such as people, stairs, tables, and walls. Route navigation or way finding is the second problem.

Among many solutions Guide Cane [2] is one of them. Guide Cane detect edges, steps by operating in a diagonal position across the lower part of the body for shelter. It mainly uses echolocation to find objects in front of the user. The limitation of Guide Cane is it doesn't support person's body weight and also damage the personal navigation method one might have developed internally.

Another solution is Drishti [3]. Drishti uses a precise location measurement system, a wireless connection, a wearable computer, and a vocal communication interface to help visually impaired. For outdoor navigation it uses DGPS as its location system to keep the user as near as possible to the central line of pedestrian lane. The drawback is that the device can only detect where potential objects are but not where a visually impaired person can roam around.

In this paper, we are proposing a solution for outdoor route navigation that overcomes the constraints of other systems. I have used a smartphone camera which is common and extremely cheaper as well. Smartphones are portable and not cumbersome. Ease of use is vital to a good system. If the user thinks that the system is too much of a nuisance to use then he may prefer not to use it.

The rest of the paper is organized as follows. In Section II, few existing models for helping visually impaired people in navigation are explained. In Section III, we have explained an outline of the system architecture. In section IV, implementation steps are described briefly. In section V, data collections and experimental results are described. Section VI contains description of the tools that we have used for developing this system. We speak on our limitation in section VII. Finally, we conclude the paper in section VIII.

II. LITERATURE REVIEW

A. Mobility of the visually impaired

Mobility means the ability to travel safely, gracefully, comfortably, independently [4]. The study of which will provide the data that is needed for the delineation of mobility aids, the improvement of training methods, and the evaluation of both. To develop a navigational system for the visually impaired we need to understand the mobility of the blind people.

According to Brambing's model [4] blind people mainly navigate by percepting objects or by processing of orientation. Visually impaired people mainly travel depending on the sense of touching and hearing. Using these information an application is developed for helping blind people to navigate safely and independently in surrounding environment. Because, visually impaired people are slender in detecting and avoiding obstacles.

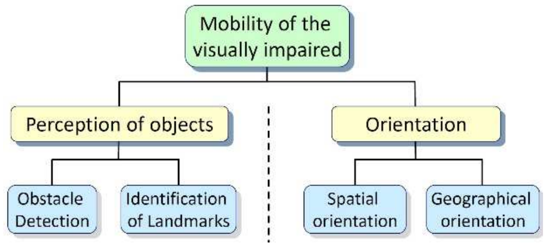

Fig. 1. Brambing's model for mobility of blind people [4]

B. Traditional Aids

There are two ways of navigation for blind people. One of them is using a white cane and the other is to use a guide dog. White cane [4] is a lightweight, cheap, cylindrical cane and good in detecting surface obstacles. But, if user uses it for a long span of time it will cause arm fatigue, muscle weakness and severe back pain. Guide Dog is used by less than <1%of the visually impaired due to high cost (~60,000 USD) of training and maintainability [4]. The dog generally walks on the left side a few of distance ahead of the user.

C. Navigation Assistance

Many different technologies have been used for navigation and localization. These systems can be classified in 3 parts. Electronic obstacle detectors, computer vision based system and GPS based system.

Examples of laser detectors are the C-5 laser cane and the talking laser cane [5]. They mainly follow Cranberg's principle of optical triangulation [6]. But, their efficiency tend to decrease against soft objects. They are not also suitable for crowded environment.

Ultrasound devices use ultrasound instead of light. It is same as echolocation. Receivers can actually change the sound into an audible range signal, so users can actually hear the hurdle around them. It works like animals such as dolphins and bats. Some of the examples of ultrasound devices are Sonic guide [7], Miniguide [8], Nav Belt [9] etc.

Some of the examples GPS based system are Personal Guide System [10], MoBIC system [11], Trekker Breeze [12], Braille Note [13], Street Talk [14]. But they are costly due to the cost of hardware and maps. Furthermore, the GPS signals are often disrupted when the user travel between tall buildings or under dense forest. Another disadvantage of GPS based system is that this system cannot detect sudden changes of the surroundings.

Computer vision systems use images captured from cameras to obtain information about the environment. Voice System [15], Brain Port [16], virtual Acoustic Space [17], Electro Neural Vision System [18], Virtual Cane are part of many trending assisting systems. The Brain Port device use visual data is attained through a small digital video camera, about 1.5cm (5/8 inch) in diameter, accommodated in the center of a pair of sunglasses worn by the user. From there, the data is transferred to a handheld base unit about the size of a cell phone. The unit changes the digital signal into electrical pulses which take the place of retina's function. The electronic-neural vision system creates electric simulation which is proportional to distances on the user's fingers for representing the detected obstacles and landmarks. But, all of these computer vision-based devices require extensive training and they are costly.

A smartphone-based system is created which is an indoor guidance system that is simple, accessible, inexpensive, and discrete to aid the visually impaired to navigate unfamiliar environments such as public buildings [19]. The system consists of a smart phone and a server. The smart phone transfers pictures of the user's location to the server. Positional data is then transmitted back to the smart phone and communicated to the user via text-to-speech. But, it requires a computer for the server and a wireless router which is costly.

Taking into account all these limitations of existing system we developed a smartphone-based real time outdoor navigational system to help the blind people which is useful, cheap and available.

III. Proposed approach

This segment will be totally based on how the system is developed.

A. Proposed Method

Navigation assistance for visually impaired (NAVI) refers to systems that are able to assist or guide people with vision loss, ranging from partially sighted to totally blind, by means of sound commands.

1. A color image is retrieved from the device's camera.
2. The color image is converted to gray-scale
3. Line is detected in the binary image using the Hough transform.
4. The detected lines are overlaid in the color image.
5. The resulting color image with detected lines is displayed on the screen of the device.
6. There is a safe zone to make sure the drawn line has not deviated horizontally.
7. If the line happens to be outside the safe zone the app sends a continuous audio feedback to the user, otherwise it does not.
8. If there is any obstacles in front of the user the app also sends audio feedback.
9. The app also detects ups and downs in the pedestrian lane.

B. Flowchart

Flowchart of the methodology is given below:

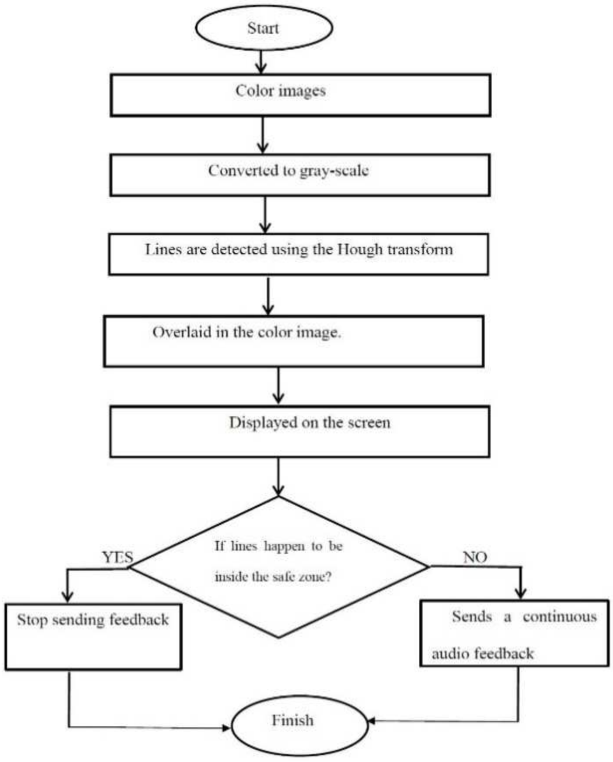

Fig. 2. Flowchart of the methodology

IV. IMPLEMNENTATION

Description of the methodology is given below:

A. Taking Real Time Video With The Android Smart Phone Camera

We used the smart phone's native camera for taking videos from the road ahead. The roads ahead need to be clear to work properly. The lines should be visible. After this step, converted this image into a grayscale image. Gray scaling image opens up a lot of new opportunities to process the image received from the camera.

Fig. 3. Grayscale image

Techniques of converting into grayscale eliminate all color information. It leaves only the luminance of each pixel. Today grayscale most image file formats assist a minimum of 8-bit grayscale, which gives 2^8 or 256 levels of luminance per pixel. Since digital images are represented using a combination of red, green, and blue (RGB) colors, each pixel has three separate luminance values. Therefore, these three values must be combined into a single value when eliminating color from an image. There are several ways to do this. One way is to average all luminance values for each pixel. This method simply averages the values: (R + G + B) / 3 [20]. We transformed color images to grayscale images for simplification of mathematics, expanding speed of the process, for decreasing complexity of the code and amount of storage and computation.

B. Running The Image Through Edge Detection Filters

We need the edges of the lane that we are going to follow to detect the lines. To do that we have to find the edges first. We are applying the canny edge operator [21].

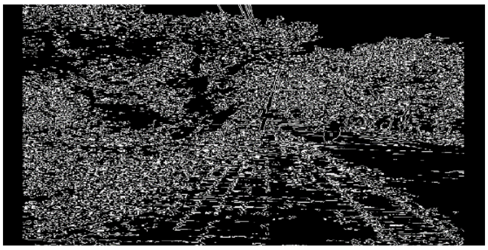

Fig. 4. Canny edge detection

It was developed by John F. Canny in 1986.The points at which image brightness changes sharply are typically organized into a set of curved line segments termed edges. In this paper, we are applying gradient based image edge detection. An image gradient means a directional change in the intensity or color in an image. Data from images can be extracted using image gradient. The gradient of a two variable function is a vector which has a magnitude and direction value.

C. Extracting Region of Interest

Region of interest to sort out the remarkable part of the image was done. In blind navigational system, it is important to keep the line perfectly bottom the user or it will not be safe. We are calling this region of interest the safe zone. The Android application identify the significant line from the image captured from the back camera and in response provides an audio feedback to the user. The main cause of ROI execution is that we would want to keep the user inclined with the detected line. If ROI isn't used the user may get audio response upon detecting the remarkable safe line but he won't be directly on it. The variance from that safe line wouldn't be perfect. Safe line means the type of line which is bold enough to stand out and there is not much obstacles on it.

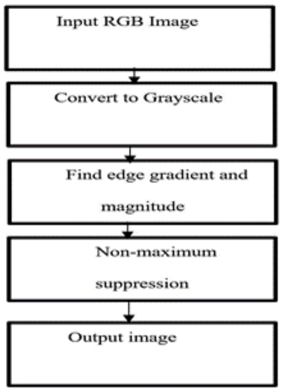

Fig. 5. Flowchart of Canny edge detection

D. Applying Segmentation and Erosion Procedure

Since the Hough transform algorithm loops through the input image and makes obvious computations at every position of a white pixel, the output image from the segmentation phase to have as few white pixels as possible, this way we had achieved better performance.

The input image which goes to the segmentation phase after detecting edges. As part of segmentation, we disregarded the top half of the input image completely shown in Fig. 6. Because it is above the horizon and lies out of ROI, therefore it is not essential and its processing would only cause degradation of performance [22].

Before erosion procedure, I need to apply local adaptive thresholding. In this method an image is divided into regions. It performs thresholding independently in each region. Every pixel in image is thresholded according to the histogram of the pixel neighborhood.

$$dst(x; y) - \begin{cases} 255 & \text{if } src(x; y) > T(x; y) \\ 0 & \text{otherwise} \end{cases}$$

Here, T(x, y) is a mean of the intensity values of all pixels in the n × n neighborhood of (x, y) minus constant C. For this, we have chosen n = 3 and C = -1.5, the lowest possible value. If we chose C = -0.5 then the value of C is too high as well as there is a very high amount of noise (insignificant white pixels) present which needs to be filtered out.

We used a 2×2 rectangle structuring element (SE) with a morphological operation called erosion which eliminated most of the noise but still left some noise present. If we used bigger dimensions for the SE, some important data could be lost, the pedestrian lane lines would become disconnected and that would make them more difficult to detect.

We also drew a thin green line at the border of segmentation (half of the screen) so the user knows where the line detection begins and can tilt the smartphone and its camera accordingly.

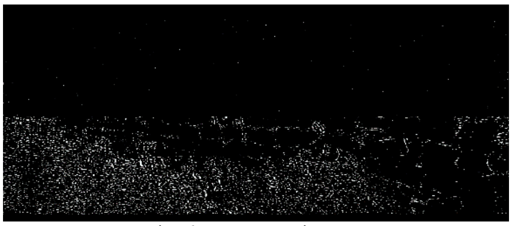

Fig. 6. Segmentation

E. Hough man Transformation

This is the most important step of the whole process. Using Hough transform we were able to detect the lane followed. Overlaying the line on the image gives us the following result. Figure 13 is a screen shot that demonstrates when the line is detected within the safe zone.

Fig. 7. Detected lines (screenshot from my application)

Red lines indicate detected lines. Hough transform algorithm is used. Because, it is tolerance of gap and noise. According to the results of this analysis an application was created which implemented different approaches in usage of Hough transform for line detection.

The algorithm for detecting straight lines can be divided into the following steps [22]:

1. Edge detection, e.g. using the Canny edge detector.

2. Mapping of edge points to the Hough space and storage in an accumulator.

3. Interpretation of the accumulator to yield lines of infinite length. The interpretation is done by thresholding and possibly other constraints.

4. Conversion of infinite lines to finite lines.

F. Audio Feedback

In the absence of vision, blind people pay heed to auditory cues and learn how to use them more masterly. Brain imaging research show the visual cortex of the blind people is overtaken by other senses, such as hearing or touch, and bestows to language processing.

This application triggers a default mp3 file upon the lane and obstacles in the region of interest.

V. Experimental Result

To collect data for all the testing and experimenting I have examined footpaths found around the CUET campus and Brahmanbaria city. Collecting good data was really difficult as most of the footpaths do not have visibly clear lines that we worked on. So, we had to take a lot of photos to compile the results.

Different types of obstacles can be seen around pedestrian lane. The app can detect those obstacles. It can also detect ups and downs in pedestrian lane. By detecting safe zone, it helps blind people to navigate surroundings.

We conducted multiple experiments in real life urban environments. we have taken almost 20 videos with an average duration of 3 minutes. This system can detect obstacles (e.g., electrical pole, rail gate crossing bar, unwanted holes, pile of bricks and sand) situated either down on the foot area or high on the waist level and detect them at a considerable distance from the user. When these obstacles are detected it gives an audio feedback. In this case the user can change his/her direction of walking in order to avoid the obstacle.

Fig. 8. Experimental result obtained using proposed detection system

While collecting data near Abdul Kuddus Makhon Milonaioton in Brahmanbaria, it was noticed an obstacle at the end of the footpath which may cause difficulty for visually impaired people. Following types of obstacle can also be seen in footpaths:

Pile of bricks and sand used for construction can also be seen in pedestrian lane. This app can detect them and send an audio feedback. But, it gives comparatively slower response while detecting sand than other obstacles. Because, here line can not be detected easily.

Fig. 9. Experimental result obtained using proposed detection system

Ups and downs can also be detected by this app. Some of the examples are given below. It also gives audio feedback when user goes out of safe zone. Here, area inside the red lines indicates safe zone. By giving audio feedback it helps a pedestrian to avoid accident.

Numbering the system out of five by the participants and majority found it efficient.

Fig. 10. Experimental result obtained using proposed detection system

TABLE I. ANSWER OF THE SEVEN QUESTIONS FROM PARTICIPANTS

Questions	Answer from Nafiza (ID:1304039)	Answer from Sadia (ID:1304032)	Answer from Sabiha (ID:1304030)	Answer from Kakon (ID:1307028)	Answer from Sikha (ID:1302022)	Answer from Shakib (ID:1304106)
Do you like this application?	Yes	Yes	Yes	Yes	Yes	Yes
How much you give score out of 5?	4	4	4	3	5	2
Is it useful for blind people?	Yes	Yes	Yes	Yes	No	Yes
Which feature do you like most?	Audio feedback	All	All	All	All	Detection
Have you heard about this type of application before?	No	No	No	No	No	Yes
Do you think any changes needed?	Yes	No	No	No	No	No
If you face any problem what is the problem?	Yes, (It doesn't detect holes)	No	No	No	No	Yes

Is this application useful for blind people?

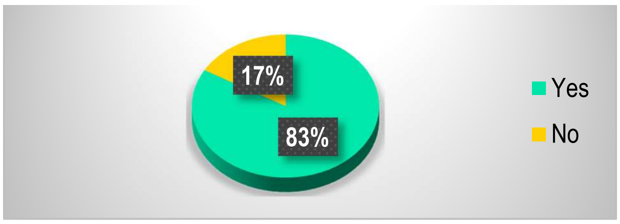

Fig. 11. Usefulness of this application

VI. TOOLS USED

In this paper, we mainly used OpenCV, android studio as coding platform and an android smartphone.

A. Android

The key elements to consider when choosing the appropriate library for a CV application that is supposed to solve pedestrian lane detection problems and run on a mobile platform are speed, low complexity, low battery consumption and android ecosystem.

B. Opencv

Taking all these aspects into account I have chosen the OpenCV library for the following reasons [23]:

- It is the most developed open source CV library with the widest communitysupport.
- It is depicted to be high performance. The algorithms are written in C++ and are compiled to a highly boosted native code, which suit sourneeds since Android runs on a Linux kernel.
- Even though the algorithms are written in C++, OpenCV preserves direct port for the Android platform
- It includes all the algorithms that can be found in a desktop version in the form of native Android libraries and at the same time gives Java interfaces for an access to those algorithms.

C. Smartphone

An android smartphone is used to record and process the images. The system is attached to the user with the help of a belt which can be worn around waist.

Fig. 12. Implementation of this system

VII. LIMITATIONS AND FUTURE WORK

Following the study presented in this thesis, improvements to the proposed approaches that could be made in the future includes:

1. Many of the streets in cities don't have significant footpath or significant edge to follow. This lack of edge will lead to halt in movement for the user.
2. This system works well in well lighted areas.
3. The user need to be placed on to the lane at first. With the first lane detected the user can move on following.

VIII. CONCLUSION

This paper presents a vision-based system designed to identify pedestrian lanes in different territory for assistive navigation of visually impaired people. This system focuses finding out the walking lane in front of the traveler in each scenario. The major tasks of the system include detecting the lane type in the video captured from the camera in real time. The experimental results have shown effectiveness and robustness of the proposed approach.

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