# Assistive guidance system for the visually impaired

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## ABSTRACT

In recent years, with the improvement in imaging technology, the quality of small cameras has improved significantly. Coupled with the introduction of credit-card sized single-board computers such as Raspberry Pi, it is now possible to integrate a small camera with a wearable computer. This paper aims to develop a low-cost product, using a webcam and Raspberry Pi, for visually-impaired people, which can assist them in detecting and recognizing pedestrian crosswalks and staircases. There are two steps involved in detection and recognition of the obstacles, i.e., pedestrian crosswalks and staircases. In detection algorithm, we extract Haar features from the video frames and push these features to our Haar classifier. In classification algorithm, we first convert the RGB image to HSV and apply histogram equalization to make the pixel intensity uniform, followed by image segmentation and contour detection. These detected contours are passed through a pre-processor which extracts the regions of interest (ROI). We applied different statistical methods on these ROI to differentiate between staircases and pedestrian crosswalks. The detection and recognition results on our datasets demonstrate the effectiveness of our system.

## 1. INTRODUCTION

Our sense of vision has developed over millions of years of evolution, and coupled with the visual cortex has been one of the key ingredients for the ascension of humans as the dominant species on our planet. Without proper vision, humans remain inert towards a wide range of stimuli perpetuating from the outside environment. Hence, there is an urgent demand for low-cost solutions which can assist people with impaired vision.

In the past few decades, many researchers and engineers have tackled this problem and developed prototypes for obstacle detection, object detection and classification using computer vision and sonar assisted obstacle detection. These solutions involve the manufacturing of customized hardware along with expensive cameras.

In the context of assistive technology, mobility takes the meaning of "moving safely, gracefully, and comfortably". It relies in large part on perceiving the properties of the immediate surroundings, and it entails avoiding obstacles, negotiating steps, drop-offs, and apertures such as doors, and maintaining a possibly rectilinear trajectory while walking. Although blind people are more in need of mobility aids, low-vision individuals may also occasionally trip onto unseen small obstacles or steps, especially in poor lighting conditions.[1]

## 2. RELATED WORK

This section reviews existing navigational assistance for the visually impaired. First, the mobility of vision-disabled people is presented in Section 2.1. Then, conventional mobility tools are described in Section 2.2. Next, assistive technologies based on computer-vision are reviewed in Section 2.3.

## 2.1. Mobility of the visually impaired

Mobility is the ability to travel safely and independently from one place to other places and is an essential aspect of daily life. Vision plays a very significant role in mobility as it allows sighted people to collect most of the information required for perceiving the surrounding environments. People with vision loss must rely on other senses (e.g., hearing and touch) to gather information about the surrounding objects, and therefore face great difficulties in traveling[2].

The mobility of blind people includes two aspects: perception and orientation. Perception refers to a blind traveler obtaining information about the environment via the non-vision senses in order to detect obstacles and identify landmarks. Orientation refers to the knowledge to recognize the position in relation to surrounding objects and the location in the routes of the entire journey. To understand the surrounding environments, vision disabled people employ touching and hearing as primary modalities [8]. In near space, both touching and hearing are used to perceive objects. In far space, the people reply mainly on hearing to find objects. Orientation is performed based on the identification of landmarks. Blind people often employ many different types of landmarks to determine their position in the environments. Example landmarks include rises and falls in the walking path, changes in the texture of the walking path, the presence of walls and hedges, traffic sounds and temperature changes.

People with vision impairments have three major barriers while traveling [3,4] as follows:

1) Relying mainly on touching and hearing, visually impaired people are limited in detecting and avoiding obstacles, finding the travel path, and identifying hazards ahead.
2) They have great difficulties in determining routes for a journey, understanding the scene layout, and identifying their position in the scene.
3) They cannot obtain visual or textual information such as road signs and bus numbers.

These barriers make visually impaired people unable to travel safely and independently in unknown environments.

## 2.2. Traditional aids

There are two popular traditional aids for navigation of the visually impaired: the white cane and the guide dog.

**The white cane** is a hand-held tool and is considered as an extension of the user's arms. This tool is a lightweight and cylindrical cane, and is often made of aluminium. It is adjustable to the height of the user and includes a purposely designed handle-grip and tip. To detect objects on the walking path, the user swings the white cane from side to side while the tip of the cane directly contacts with the ground. Based on vibrations and force feedback from the cane, the user can recognize objects ahead and characteristics of the ground. To effectively use a white cane, blind people often require about 100 hours of training [3], because an incorrect use of the cane can lead to dangers for both the user and others.

The white cane is a cheap, reliable and robust tool to detect obstacles and drop-offs at ground levels, identify the characteristics (e.g., texture and hardness) and conditions of the ground, and find the walking path at close range [4]. However, this tool is unable to detect obstacles at torso and face levels, which are dangerous for blind travelers [3, 4]. Furthermore, using the white cane over a long distance causes arm fatigue for travelers [4].

**The guide dog** is a specially trained dog to assist the blind in mobility. A blind user can travel safely with a trained dog. The dog is trained to have the following major skills [5]:

- Walking in a straight line and on the left-hand side slightly ahead of the user.
- Stopping at all curbs, the top, and bottom of stairs.
- Waiting for user's commands before crossing roads.
- Avoiding obstacles at head level.
- Avoiding narrow spaces where a person and a dog cannot walk through side by side.
- Boarding and traveling on all different types of public transportation.
- Taking the user to a lift.
- Refusing the user's commands that may cause dangers for the user.
- Recognizing the familiar routes.

The user controls the guide dog and receives information about its activities via a handle encircled the dog's chest. With the above trained skills, the guide dog provides assistance for safe travel to vision-disabled people in familiar environments. However, a guide dog typically requires about two to three years and 40,000 USD to train and has a working life of only eight to ten years [3]. Due to the high cost of training and maintenance, just three percent of the visually impaired population is reported to use a guide dog. Furthermore, the guide dog cannot detect obstacles at head levels.

Both the white cane and guide dog are useful aids for blind travelers in detecting and avoiding obstacles at ground levels in the near space. However, these tools cannot assist blind travelers in determining spatial and geographical orientations, recognizing locations and finding routes for their journey in unfamiliar environments.

## 2.3. Technology aids

Many assistive technology systems have been developed to improve the mobility of vision disabled people. Some computer-vision based assistive systems are explained below.

**Computer-vision based systems**

Computer-vision based systems use images captured from cameras to obtain information about the environment. Many studies have been conducted on assistive navigation of blind people. The Virtual White Cane system[14] detects objects using a smartphone and a laser pointer as shown in Fig. 2.1. The object's distance from the user is estimated from the image of the laser's reflection off the planar surface, using active triangulation. The image is captured by the camera of the smartphone. The detected objects are conveyed to the user through vibration of the smartphone.

Several vision-based systems focus on detecting crossings of zebra patterns at traffic junctions for the visually impaired [6, 7, 8]. These systems apply the image processing and pattern recognition techniques to detect lane markers in the image captured by a camera, and determine then the walking region for users. For example, Se proposes an assistive system to find the zebra-crossing lane in the image [7]. The walking lane is determined by finding lane markers using the Hough transform.

In [8], Ivanchenko *et al.* design the Crosswatch system that employs a mobile phone to find and locate zebra-crossings as shown in Fig 2.2. The authors proposed using a graphical model with geometric and color cues to find the borders of lane markers in the image captured from the phone camera.

In [7], Uddin and Shioyama employ the bipolar feature of zebra patterns to segment the crossing region and verify the detected crossing using the constant width periodic feature of white bands in a zebra-crossing. The system by Radvanyi *et al.* segments first the crossing region using color features, and then verifies the detected region by finding the lane markers with an adaptive thresholding technique [8].

In general, most existing assistive systems based on computer-vision focus on detecting obstacles.

## 3. APPROACH

This paper proposes a robust approach for the identification of staircases as well as pedestrian crosswalks adaptive towards varying lighting conditions.

- Capture frame through webcam.
- Apply classifier.
    - Object Detected
        - Convert original image to HSV color scale. Split image into H, S and V. Select V matrix and assign to *image* matrix for further calculations.
        - Apply CLAHE to the *image*.
        - Apply image segmentation and threshold to differentiate dark and light spots.
        - Find contours and traverse through all contours to remove the outliers. Apply following conditions:
            - ❑ Ratio of minor axis and major axis of ellipse.
            - ❑ Area of ellipse.
            - ❑ Orientation of ellipse.
        - Apply LIS(Longest Increasing Subsequence) algorithm to find the number of ellipses which can be part of the zebra-crossing.
        - *if len(sequence) >= 4*:
          **"Pedestrian Crosswalk"**
          *else:*
          **"Stairs**
    - No object Detected

TABLE 1: PROPOSED ALGORITHM

### 3.1. Identification of Staircase and Pedestrian Crosswalk

The first step involves image acquisition through suitable hardware, which in this case is a USB webcam. The next step involves the identification of any staircase like object in the acquired image and draws a boundary around it. The identification is done through Haar's feature-based classifier.

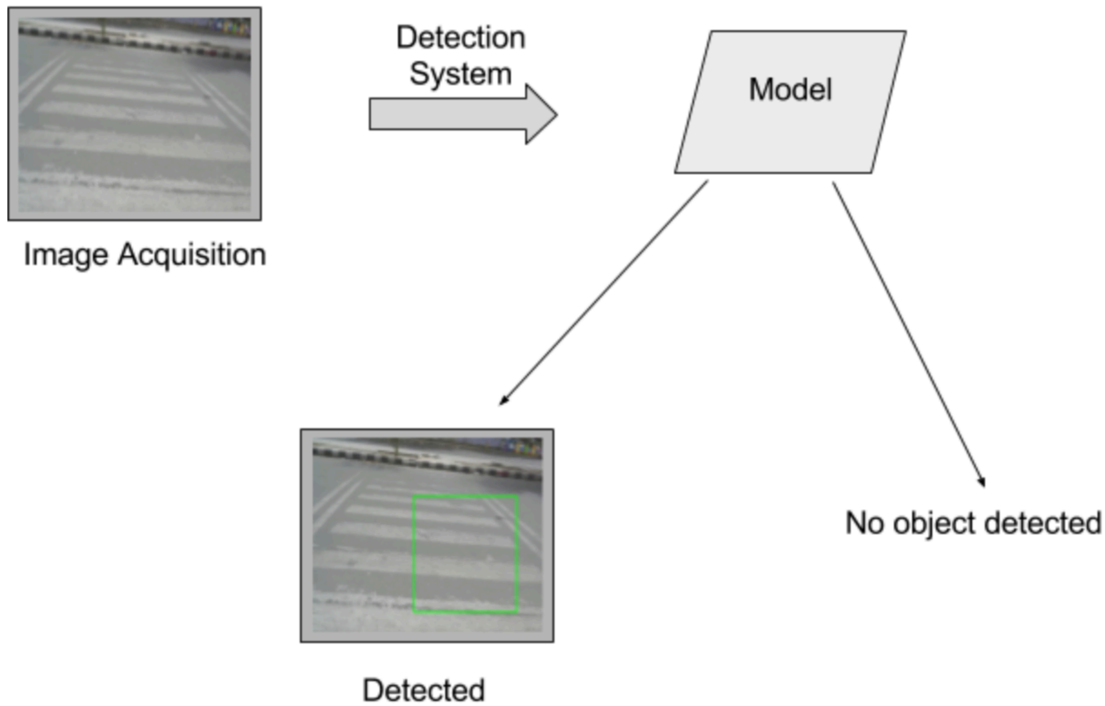


FIGURE 1: FLOW CHART OF DETECTION SYSTEM

**3.2. Classification between Stairs and Crosswalks**

Upon detection, histogram equalization is applied to the acquired frame which increases the contrast of the image. Segmentation and thresholding are subsequently done to highlight the white and black patterns in the image which helps in differentiating zebra-crossings from staircases.

In the next step, contours are found in the observed frame and ellipses are drawn over them. The distances between individual ellipses are found and are arranged in increasing order. If the length of the longest increasing subsequence is found to be higher than 4 (this number is obtained through repeated field observations), then a prediction of zebra-crossing is made otherwise a staircase is predicted.

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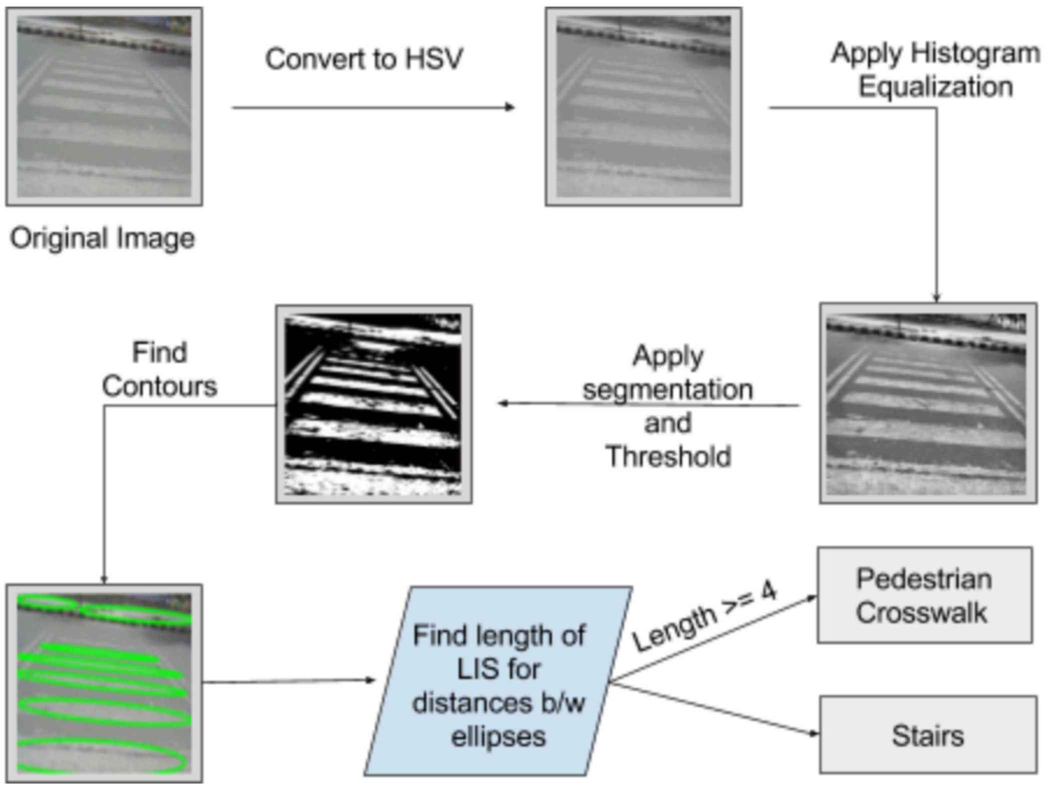


FIGURE 2: FLOW CHART DEPICTING IMAGE PROCESSING TECHNIQUES

### 3.3. Companion Android application

An Android application was built for activating the detection system through touch gestures. The application also provided audio feedback for identified obstacles.

#### 3.3.1. Activation

In computing, multi-touch is technology that enables a surface (a trackpad or touchscreen) to recognize the presence of more than one or more than two points of contact with the surface. This plural-point awareness was used to implement additional functionality, such as pinch to start the data gathering, and the reverse gesture to deactivate the system.

FIGURE 3: GESTURE

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### 3.3.2. Communication between phone and Raspberry-Pi

To establish communication with the Android smartphone the Raspberry Pi is configured as a Wi-Fi hotspot with WPA2 secure encryption. The phone is connected to this network with this one-time process. The Pi then starts broadcasting signals upon activation from the user's end. If a staircase or a crosswalk is identified, a UDP packet is generated and sent to the Android smartphone using Wi-Fi as the carrier.

### 3.3.3. Voice-over for audio feedback

Google Text-to-Speech is a screen reader application developed by Google Inc for its Android operating system. It powers applications to read aloud (speak) the text on the screen. In this implementation, it is used provide audio cues to the blind user so that he/she can avoid or maneuver the identified obstacle.

## 4. EXPERIMENTS AND RESULTS

In this paper, the proposed system was tested in different environments with different lighting conditions. We captured ~1200 frames in different environments and calculated the true positives and false positives. We observed that in low visibility areas, the performance of the system decreases, but it is still satisfactory. In the areas with sufficient light, we observed that the system accurately identifies staircases and zebra crossings most of the time.

| Visibility | True Positives (%) | False Positives(%) |
|---|---|---|
| Low (Indoor) | 52.33 | 14.88 |
| Sufficient(Indoor) | 72.12 | 4.13 |
| High(Outdoor) | 74.47 | 4.91 |

TABLE 2: ACCURACY OF THE SYSTEM

Here is a video showing the system in action – https://youtu.be/5gA2s16UuW4

## 5. CONCLUSION

The primary goal of this paper was to develop a low-cost wearable prototype for visually impaired people. The prototype can be used by them to detect and maneuver obstacles such as staircases and zebra-crossings. A thorough overview of the fundamentals of computer vision was presented, including the conclusions of historical research and newly proposed techniques. The shortcomings of various image processing techniques were discussed, and benefits of using one algorithm over the other were elaborated.

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