A HYBRID APPROACH FOR IDENTIFICATION OF MANHOLE AND STAIRCASE TO ASSIST VISUALLY CHALLENGED

Seminar Report

*submitted in partial fulfillment of the requirement
for award of Degree of*

BACHELOR OF TECHNOLOGY

In

COMPUTER SCIENCE AND ENGINEERING

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APJ Abdul Kalam Technological University

Submitted by

DILNA V

Department of Computer Science and Engineering
**Mar Athanasius College of Engneering
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CERTIFICATE

This is to certify that the report entitled **A Hybrid Approach for Identification of Manhole and Staircase to Assist Visually Challenged** *submitted by* **Ms. DILNA V**, *Reg. No.* **MAC15CS025** *towards partial fulfillment of the requirement for the award of Degree of Bachelor of Technology in Computer science and Engineering Engineering from APJ Abdul Kalam Technological University for the year 2018 is a bonafide record of the seminar carried out by her under our supervision and guidance.*

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ACKNOWLEDGEMENT

ABSTRACT

Recognition of an object is a bare minimum restraint for an individual in order to sort out or classify the type of the object. To assist visually challenged persons while recognizing the staircases and manholes. A prototype of mobility recognition is presented using Feature Vector Identification and Sensor Computed Processor Arduino chips. A low weight stick is developed using Arduino kit along with feature detection module and helps the visually challenged in reaching their destinations with ease. In order to recognize the manholes, the chip is programmed and embedded in the stick which also holds the code for detection of the staircases based on Bivariate Gaussian Mixture Model (BGMM). SURF algorithm is considered for extraction of features. The developed model shows an accuracy of around 90% for manhole detection.And 88% for staircase detection.

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List of abbreviation

SURF   Speed Up Robust Features

SVM   Support Vector Machinel

BGMM   Bivariate Gaussian Mixture Model

USB   Universal Serial Bus

TP   True Positives

FP   False Positives

ETA   Electronic Travel Aids

Introduction

Moving around unfamiliar surroundings is an exigent task for the visually impaired persons due to their deficiency in eyesight. According to the latest survey, around 1.5 million people in India are visually challenged and are facing a hardship in performing their day to day activity. This population is about 170 million worldwide and as per the latest statistics, this number is increasing by 10% annually.

Staircases pose a major problem in navigation, and their recognition is of prim importance for the visually impaired. Many different kinds of sensors, like monocular and stereo cameras, depth sensors, or laser scanning devices (e.g., LiDAR), have been used for detecting staircases.

Blind people suffers a lot in the recognition of object and is a bare minimum restraint for an individual in order to sort out or classify the type of the object. This situation becomes a tricky experience with respect to the blind persons; therefore to assist visually challenged persons, in particular, while recognizing the staircases and manholes, a prototype of mobility recognition is presented using Feature Vector Identification and Sensor Computed Processor Arduino chips. This prototype provides more sovereignty to the sightless people while walking on the roads and helps to pass through on their own without any backing.

The prototype is developed using Arduino kit along with feature detection module and helps the visually challenged in reaching their destinations with ease. A low weight stick is built to facilitate the visually challenged people towards effective recognition of the obstacles. In order to recognize the manholes, the chip is programmed and embedded in the stick which also holds the code for detection of the staircases based on Bivariate Gaussian Mixture Model (BGMM); SURF algorithm is considered for extraction of features Reference[1].

In this paper we propose a hybrid approach for detecting manholes and staircases by using both sensor and image based algorithms. We present a novel algorithm to detect and classify upward and downward staircase from high quality frames extracted from a video stream of a mobile camera using Bivariate Gaussian Mixture Model that takes as an input staircase shape and distance features extracted using the SURF algorithm. The entire processing happens on the smartphone without need of heavy computation devices or high speed 3G/4G connectivity for cloud computation. We use an array of 3 sonars (front, right and left) mounted on a white

cane and managed by Arduino processor to help detect manholes and also aid in staircase navigation. We further use median based threshold using Gaussian Mixture Model for precise manhole identification.

This hybrid approach employ vibro-feedback mounted on the cane to warn the user of the obstacle as well as connect to smartphone via Bluetooth for audio feedback. Overall the system is lightweight and cost effective.

Related works

Monocular image based methods generally detect staircases by detecting non-ground plane regions and identifying pattern of concurrent lines resembling staircases in those regions. For example,Se S. and Brady M proposed a Gabor filter based texture detection method to detect distant staircases. They estimated the staircase pose by homograph search model. Hernández D. C., Kim T. and Jo K. H. "Stairway Detection Based on Single Camera by Motion Stereo" extended this using motion stereo. Yashas M., Maalik K. S., Ashfaq M. Z. M., De Silva K. P. S. H. and Ragulan S, detected staircases only from RGB Reference[2] image by
performing Hough transform to extract concurrent parallel lines in an edge map image resulting from Sobel operator.

Real-Time Staircase Detection From a Wearable Stereo System optimally detected staircase in real time using stereo imagery to estimate ground plane and temporal consistency, but did not classify up/down stairs separately.Stereo Camera Based Virtual Cane System with Identifiable Distance Tactile Feedback for the Blind, Sensor incorporated a stereo camera into the white cane and used actuators for guidance and distance feedback.

Detecting Stairs and Pedestrian Crosswalks for the Blind by RGDB Camera proposed an RGBD image-based detection approach of stairs, pedestrian crosswalks, and traffic signs, which achieved decent detection rate in the staircase detection, but did not handle the escalator detection. However, some items which contain parallel lines such as bookshelves could be misclassified as stairs and pedestrian crosswalks. Depth-aware Indoor Staircase Detection and Recognition for the Visually Impaired by Munoz R, Rong X, and Tian Y presented an efficient optical flow based stair tracking algorithm using Hough transform for parallel line detection and a SVM Classifier to detect indoor staircases and recognize the types of staircases by using RGBD videos captured via RGB-D camera mounted at the chest position.

Safe Local Navigation For Visually Impaired Users with a Time-of-Flight and Haptic Feedback Device used array of Lidars and vibro-tactile units to detect obstacles and features including up/down staircases. The system is time consuming to get used to by a visually

impaired user and needs to adapt to the rate of motion of the user.

In Indian context, open manholes pose another critical risk. Ultrasonic sensors have been used extensively in obstacle detection. Reference [4] proposed use of ultrasonic sensors to detect manholes. The Smart Cane reference[4] and the UltraCane/Batcane,A Master Trainer Class for Professionals in Teaching the Ultracane Electronic Travel Device", Journal of Visual Impairment Blindness Mobility at: The Batcane (Ultracane) Assistive Technology Reference[6]for Visually Impaired and Blind People were systems that fully relied on a white cane and only used a single sonar sensor attached to a cane to detect above-knee obstacles in the direction of the cane, signaling this through a vibration.

The proposed method

3.1 Hardware components

Ultrasonic sensor implanted in the stick spots the obstacles ahead using ultrasonic waves. If the sensor senses an obstacle the output of receiver gets activated and this change will be identified by Arduino Processor. Thus, it instantaneously alerts the person as soon as it receives the triggered output. This technique can also be used to detect manholes. The device sends the waves, depending upon the obstacle, the device generates a vibration.

3.1.1 Ultrasonic sensor

These are largely used to capture the signals more swiftly, the signals from the ground level ultrasonic sensors are converted into time domain using the feature transformation. The majority of the literature in this direction depicts various models based on different sets of the ultrasonic sensor and extract the signals captured using both time domain and the features extracted for identification of the object. The time domain helps to capture principle components of the segment and helps to process the signal.

Confined to the identification of correlation coefficient by the time domain, a signal can be made to sensitize and thereby help towards the replacement of the objects. However, compared to the time domain, frequency domain, acquired signals will always give better results because of the fact that they take the statistical parameters into consideration such as movements, segments, etc. Most of the research work in this area is based on Neural Networks which can in particular help to identify the 2D and 3D shape of the objects, independent of orientation and based on the echoes generated by ultrasonic sensors.

With this advantage, some researchers have highlighted the usage of ultrasonic transducers for identifying the simple objects such as a cylinder, edge, etc. Works are also highlighted based on sonar based, particularly during the cases of corners plains and edges recognition.

Ultrasonic   sensors are mostly considered for identifying the distance; the technical

specifications of this sensor are given below

- Operating Voltage: 5V

- Static current: 2mA max

- Induction Angle: 15

- Detection Range: 2 – 400cm

- High precision up to 3mm

Figure 3.1: Ultrasonic Ranging Module HC - SR04

Every Ultrasonic sensor consists of 4 pins, namely, Vcc (5V), Trig, Echo, and GND (Figure 3.1). Trig (trigger) aims towards sensing an ultrasonic high-level pulse for at least 10s and the Echo pin then automatically detects the returning pulse. It also encompasses the capability of measuring the distance by calculating the echo between the sending times to the return time using the formula

$$Distance = \frac{(Time\,for\,wave\,to\,return * Speed\,of\,sound)}{2}$$
(Equ:3.1)

3.1.2 Vibrator

A vibrator (Figure 3.2) is a mechanical device to generate vibrations and is mainly used to generate vibrations when the blind person is also a deaf. The vibration is often generated by

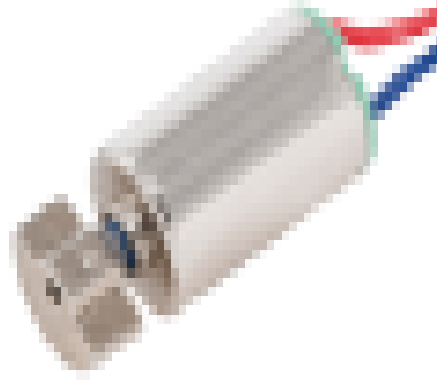an electric motor with an unbalanced mass on its driveshaft.

Figure 3.2: Vibration motor, 3 V, 150 mA, 10,000 rpm

We use VM 0610 A 3.0 Vibrator motor operating on 3V 150mA, capable of 10,000 rpm and measures only 6mm in length. It is user-friendly motor, which can be used with a variety of products. This includes pagers, GPS devices, mobile phones or even toys.

3.1.3   Sensor range

The sensors that are considered for this article can identify the objects within the range of 3 meters and are capable of identifying the objects towards the angle of 90 degrees. In the present article, the recognition of an object is carried out by estimating the distance between the sensors. The distance is identified using the two sensors in such a way that if the value of the first sensor is higher than the other sensor it is estimated as an object. The ultrasonic sensors are attached to the PVC pipe to enhance the capturing scenarios and low pass filters are used for this purpose. Several features can be extracted using these sensors, such as mean and standard deviation. Courtesies helps to estimate the ascending and descending steps more accurately. Several researchers have employed these sensors to augment the functionality of white cane used by visually challenged. The works presented are mostly focused towards the detection of the object along with the distance, without giving the importance about the nature of the object, which in certain cases may be more significant to the user. The majority of the works developed in this regard are confined towards the identification of the objects basing on statistical approaches, where the data is classified into four types namely edge, plane, corner and cylinder. Some systems were also developed with an aim to identify the

activity of the people based on the trajectory that helps to classify the scenes as the indoor or outdoor. Moreover, these systems cannot identify the manholes and descending staircases exactly.

3.1.4   Arduino

It is an open source software, which is developed by using single-board microcontrollers and microcontroller kits during the development of digital devices and interactive objects, which can sense and control objects (Figure 3.3). Arduino boards are designed based on an array of microprocessors and controllers. These boards are embedded with a set of pins which are primarily used for the digital input and analog output (I/O). These pins can be interfaced with the variety of expansion boards (shields) and other circuits for establishing both serial communications interfaces, along with Universal Serial Bus (USB). The pre-programmed boot loader is mostly used in Arduino microcontrollers which assist during the loading of programs to the on-chip flash memory. A serial connection is considered while loading the programming codes to another computer.
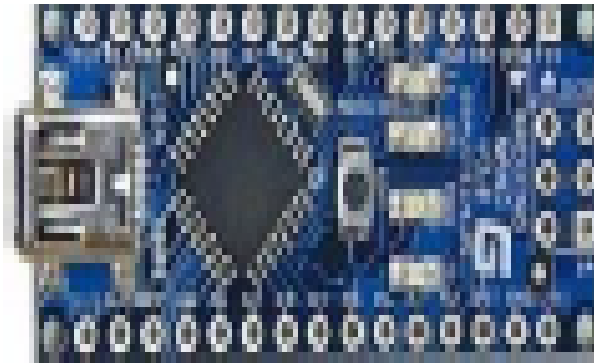

Figure 3.3: Arduino Nano 3.x board used

Hardware Features are

- Microcontroller: ATmega328

- Operating Voltage: 5 V

- Flash Memory: 32 KB

- Clock Speed: 16 MHz

- Analog IN Pins: 8

- Digital I/O Pins: 22

3.1.5 HC-05 Bluetooth

In order to carry out the wireless serial connection Bluetooth HC-05 module (Figure3.4) is considered in this work. The reason for the usage of this Bluetooth module is that it establishes a master-slave configuration (by default it works as a slave and can be configured by AT commands to behave either as master or slave) which aids in better transmission during the wireless communication process. Another advantage for the usage of this Bluetooth module is that it uses a 2.4GHz radio transceiver and baseband, which enhances the data rate as it integrates Bluetooth V2.0+EDR with 3Mbps Modulation. This chip consists of an Adaptive Frequency Hopping Feature with CMOS technology.
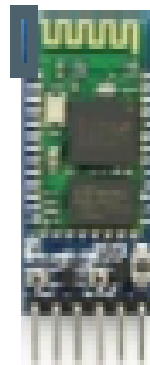
Figure 3.4: Bluetooth V2.0+EDR Chip

Typical -80dBm sensitivity

Hardware features

- Up to +4dBm RF transmit power

- 3.3 to 5 V I/O

- PIO (Programmable Input/Output) control

- UART interface with programmable baud rate

- With integrated antenna

- With edge connector

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Software features

- Slave default Baud rate: 9600, Data bits: 8, Stop bit: 1, Parity: No parity

- Auto-connect to the last device on power as default

- Permit pairing device to connect as default

- Auto-pairing PINCODE: "1234" as default

pin description

The HC-05 Bluetooth Module has 6pins, significant among them are highlighted below

Figure 3.5: Schematic Diagram

Enable: Communication channel fails when the enable is pulled LOW. When enabler is left open or connected to 3.3V, the communication establishes and will be communicating with other processors as long as this module remains in the HIGH position. The various commands are processed using the second pin, Vcc indicating supply of voltage and GND

TABLE 1
PIN CONNECTIVITY

Arduino Pins Used	Connected Device Pin
D2	Trigger Pin of Front Sensor
D3	Echo Pin of Front Sensor
D4	Trigger Pin of Right Sensor
D5	Echo Pin of Right Sensor
D6	Trigger Pin of Left Sensor
D7	Echo Pin of Left Sensor
D8	Trigger Pin of Bottom-Rear Sensor
D9	Echo Pin of Bottom-Rear Sensor
D10	Trigger Pin of Bottom-Front Sensor
D11	Echo Pin of Bottom-Front Sensor
D13	Vibrator
Rx	Tx of Bluetooth
Tx	Rx of Bluetooth
5V	Common +5V to all Devices
GND	Common Ground(-) to all Devices

Figure 3.6: Table 1:Pin connectivity

indicating the Ground Pin. It also uses two other pins meant for UART interface communication namely TXD and RXD.

State: It acts as a significant needle by which the process of the signal can be understood. The status of the signal is indicated as low, whenever it gets connected to another Bluetooth device. At this point, the status of the signal specifies HIGH and simultaneously whenever a LED light flashes, it indicates that the pairing has not been established. When the module is not connected to another Bluetooth device or paired with any other Bluetooth device, the signal goes Low.

Button Switch: In order to establish a connection for transfer of data between the Bluetooth, first of all, the switch module in the Bluetooth device is to be set in enable mode, which is possible using AT commands. Figure 3.4 and Table 1 depict the schematic diagram of the connectivity of the pins.

3.2   Identification of manholes

In order to identify the manhole, in this article, we have developed a hybrid method using the threshold values; the architecture of the recognition procedure is given in figure 3.7. The

manhole sensor facing towards the ground is attached at the bottom of the stick. It reads the signals from time to time and whenever a vacuum is identified, it reflects the signal back through the ultrasonic waves. This vacuum is then converted into distance by considering following distance formula where speed of sound in air = 340 m/s.

$$Distance = \frac{(speed * time)}{2} \qquad \text{(Equ:3.2)}$$

Initially, the value of distance is divided by 2 as it is a summative distance since the ultrasonic wave travels back and forth from source to the receptor after hitting the target.
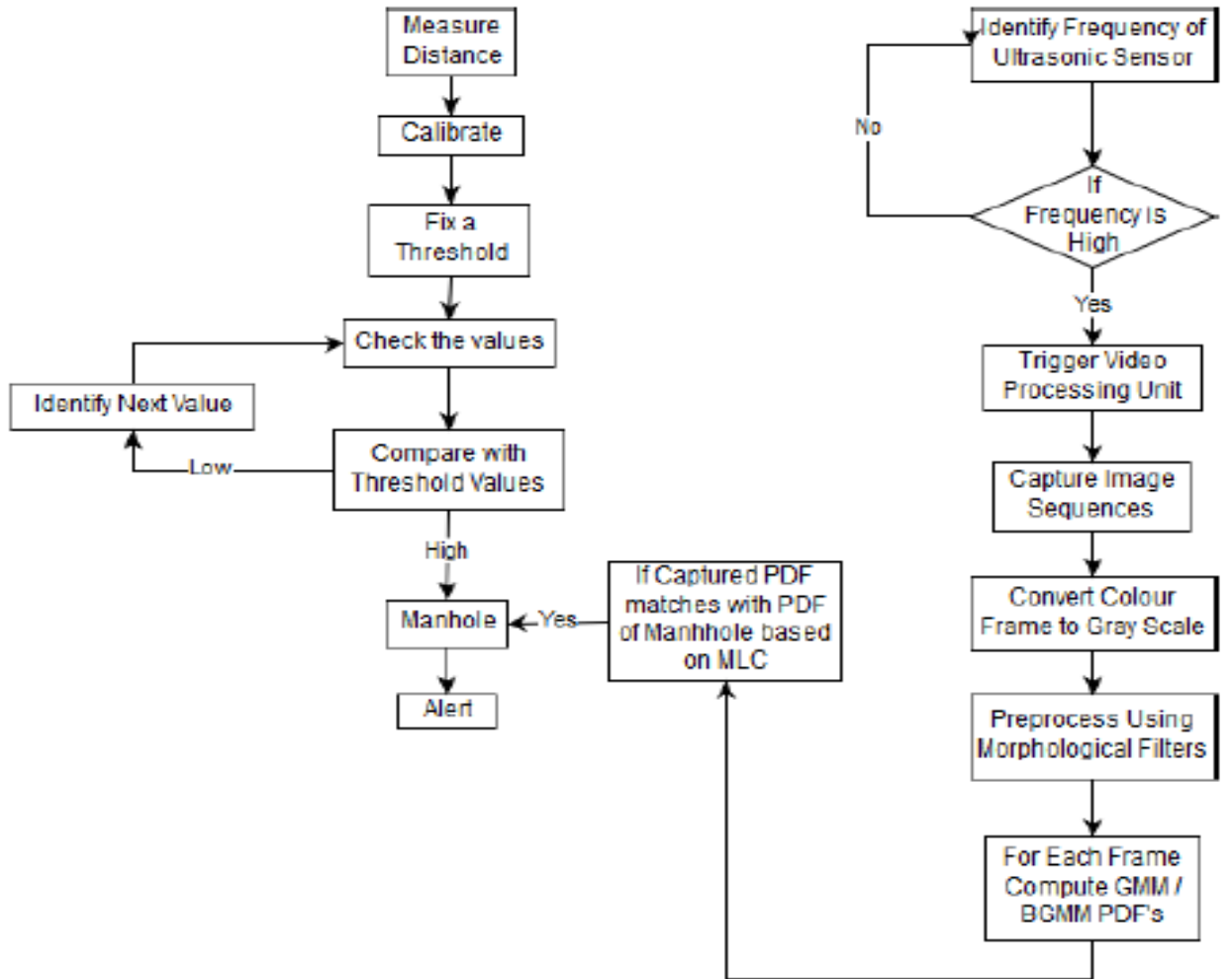

Figure 3.7: Architecture of the manhole detection

3.2.1 Threshold values

A threshold value is set and is compared with the distance value. If the distance value is above the threshold (Table 2), it is considered as a manhole, else it is not. Manhole detection calculation involves the threshold value considering the various patterns of holding the stick (it is assumed that every individual holds the stick in different ways), which is then used for detecting a manhole on the user's path.

Assuming that a single value may mislead the setting of the threshold value, a sequence of ten values are recorded by considering the stick positions in different angles in front of the manhole and calculating the distance. The average value is computed using the formula depicted below.

$$Avg - value = \frac{(sum \ \ of \ \ 10 \ \ values)}{10} \qquad \text{(Equ:3.3)}$$

The process is repeated at random several times and the maximum average value recorded is set as the threshold.

$$Threshold = maximumamongtheavg - values \qquad \text{(Equ:3.4)}$$

TABLE 2
ESTIMATION OF THE THRESHOLD VALUE

Estimating the threshold value for different inputs (chosen randomly)	Threshold Values (cm) (after calculating the average value)
6,9,8,12,11,19,10,8,7, 5	9.5
3,6,9,8,7,13,12,18,15,5	10

Figure 3.8: Table 2:Estimation of the threshold value

The Arduino processor helps in estimating the distance from the ground in each and every loop, and the readings of the ultrasonic sensor are computed and compared with that of the threshold values. Any value that is above the threshold value indicates the possibility of the presence of a manhole ahead of the user and the Arduino sends a value to the application to warn the user.

The android application is considered for alerting the user about   the various   signals

TABLE 3
ESTIMATION OF THE MANHOLE

Status	Output	Distance from ground	Result
Manhole present	"Manhole detected"	10	accurate
Manhole not present	"Manhole detected"	12	error
Manhole not present	no output	9.5	accurate

Figure 3.9: Table 3:Estimation of the manhole

received from the sensors. When a manhole or an obstacle is identified, a text voice is generated to alert the user and also generates a vibration sound so that the deaf person can also get an alert. The developed app also helps to provide the user with the position of the manhole (front, left or right).

Table 3 depicts the estimation of a Threshold value for Manhole detection. The performance of the system is tested using Metrics like precision, Recall and F-Measure and the Formulas for calculating the above are given by

$$Precision = \frac{TP}{(TP + FP)} \qquad \text{(Equ:3.5)}$$

Where TP denotes total number of manholes correctly classified and FP denotes wrongly classified manholes. The formula for Recall is given by

$$\frac{TP}{(TP + FN)} \qquad \text{(Equ:3.6)}$$

Where FN denotes the Manholes being not detected. FMeasure is calculated using the formula

$$\frac{Precision * Recall}{(Precision + Recall)} \qquad \text{(Equ:3.7)}$$

3.2.2 Threshold identification based on median value

The ultrasonic sensor activates whenever it receives the pulse of 10 ms. It has two transducers; one for transmitting and second for getting the reflected waves, if the frequency of the received wave is high, the voltage divider embedded triggers the video processing

unit, which starts capturing the image sequences, filtering process removes the noise and then attribute extraction is considered for object identification. In this process, the ultrasonic sensor transmits continuous signals upon the recognition of an object, a beep sound along with vibrations will be generated and automatically the camera attached to the model gets converted into video mode and starts capturing the video sequences. If the frame intensities remain stationary then the object is considered as stationery and if there is any change in frame intensity it is considered to be a moving object.

The increase in the frame size confirms that objects are approaching, else moving away. In our present article, we confine to manhole identification, so only stationery objects are taken into account.

During the course of video acquisition, the colour frames are changed into grey scale as intensity measurements act well in grey scale. In order to conquer the unexpected environment intensity changes, we compute the mean of every frame. We then take the average of the frames as the reference frame and compare it with the current frame to set the background and the foreground.

Threshold based techniques also help to identify the background and foreground. If the computed threshold value is greater, it is assumed to be foreground else background, generally we assign the values 0 and 1 for this purpose. We manually select the threshold value. If the image is free from noise and having a uniform back ground, then median can be chosen as the threshold value.

If the camera is in motion we need to capture the object more precisely. Because the blind persons cannot stay steady, some movement is generated automatically and this movement can cause an error during object detection. In order to overcome the error, a morphological filter is considered.Morphological image processing is a collection of non-linear operations related to the shape or morphology of features in an image, such as boundaries, skeletons, etc. In any given technique, we probe an image with a small shape or template called a structuring element, which defines the region of interest or neighborhood around a pixel.

The morphological filter helps to remove the unwanted pixel value so that the exactness in identification is possible. The morphological closing operation is considered and applied to the structural element B, Such that$A \cdot$ B = (A $\ominus$ B) $\oplus$ B, where the structuring element B is given by the following 3×3 matrix:

For accurate classification and identification of the manhole, the Gaussian Mixture Model (GMM) model is considered. The main objective behind the consideration is that, in any image under consideration, there will be finite number of Grey-level probability density functions, say 'k', and each pixel distribution can be modelled by one Gaussian function which

represents one object in the image. With this assumption, the whole image can be modelled by a mixture of 'k' component Gaussian distributions in some unknown proportions π_i, i = 1,2,3, . . , k. The probability density function of the model is given by

$$f_i(\frac{x}{\theta}) = \sum_{i=1}^{k} \pi_i f_i(\frac{x_i}{\theta_i}) \qquad \text{(Equ:3.8)}$$

Where xi denotes the image pixels, π_i denotes the mixing weight, such that

$$\sum_{i=1}^{k} \pi_i = 1 \qquad \text{(Equ:3.9)}$$

Here θ represents the parameter set and is given by $(\pi_1,\pi_2,...\pi_k, \theta_1,\theta_2,...\theta_k)$, f_i denotes the density function of the Gaussians parameterized by

$$\theta = (\mu_i, \sigma_i) \qquad \text{(Equ:3.10)}$$

The database of manholes is considered as input and each of these images is modeled using the GMM, and the corresponding probability density functions are stored. Whenever the blind person navigates through the road and encounters an object, automatically the camera captures the image and processes the image. The image is clustered and the PDF of the image is obtained and based on the maximum likelihood estimate, the nearest match with that of the images in the database, a warning message is sent back to the blind along with vibrations, so that the blind person can understand that there is some obstacle ahead and he needs to be alert.

3.3   Staircase detection

We use dual strategy to identify both ascending and descending staircases - Image based strategy for identifying staircases and ultrasonic sensor based strategy for actually navigating through the staircase.

3.3.1   Speed up robust features based Staircase Detection

Since we use the camera on the mobile device, we rely upon monocular vision based approaches rather than stereo or depth sensor. In order to sense the background, Monocular Vision Based Approaches use techniques like texture segmentation, motion and ground plane recognition, inverse edge detection and identifying concurrent parallel lines, etc. However, in practice, ground plane detection is mostly preferred because of its simple features. Ground plane detection, segments every image into two partitions based on the features as ground and non-ground. The nonground planes are further categorized into staircases or objects.

The image is separated into two regions: ground and nonground, by using the segmentation process. The possibilities of additional obstacles are checked in the non-ground region. Feature extraction process is utilized for obstacle checking. Many feature extraction models are listed in the literature , among these methods, in this article we have considered the SURF (Speeded up Robust Features) method because of the advantages like illumination, rotation, scale and computational simplicity. The features are extracted based on the attributes like blobs, corners, etc. The features of nonground image features are considered for the differentiation of ascending staircases and descending staircase.

Figure 3.10 describes the basic steps used in staircase detection, which includes video as an input and then preprocessing is done to select the high quality frames followed by segmentation and feature extraction. Segmentation divides image into two parts: ground plane and non-ground plane. Here non-ground plane will be checked further for the ascending stair case and descending stair cases. The shape of the steps and distance are considered as features, which we extract using SURF algorithm. These features are useful to decide whether a staircase is ascending or descending. These features are given as the input for the Bivariate Gaussian Mixture Model that estimates the probability density function (PDF). The PDF of both ascending and descending staircases is also considered and based on the values of the PDF, the peak is estimated and the alert is generated and is passed as a message to the visually impaired.
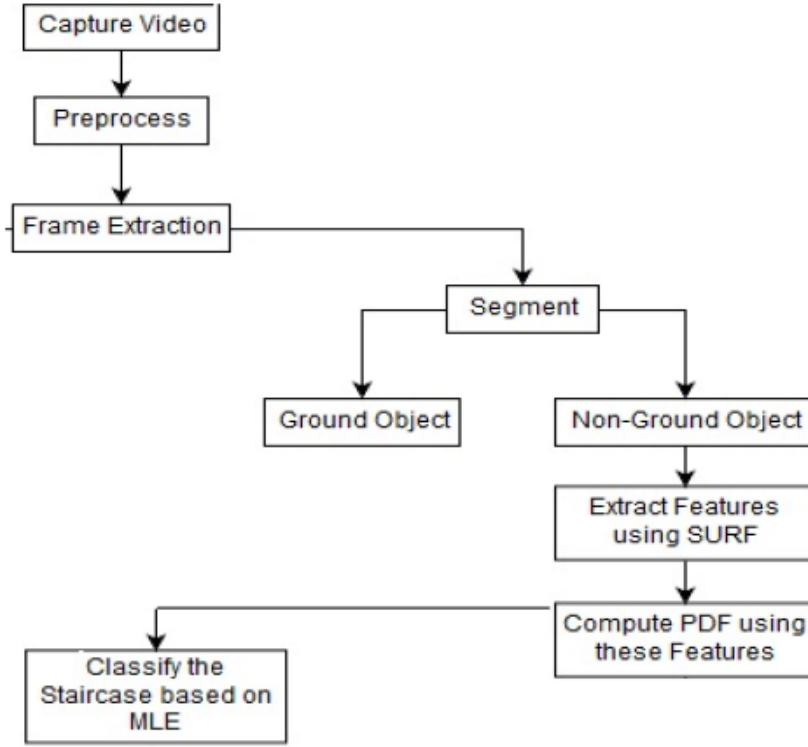
Figure 3.10: Methodology for identification of staircase based on BGMM

3.3.2 Bivariate gaussian mixture model

BGMM classifier has the ability to work with data in high dimensional space and handling of bivariate features. Hence it helps to identify the steps which are ascending and descending more accurately.

The probability density function of the pixel intensities is given by

$$f(x_1, x_2) = \frac{1}{2\pi\sigma_1\sigma_2(\sqrt{(1-\rho^2)}} e^{-(\frac{1}{2(1-\rho^2)}[\frac{x_1-\mu_1}{\sigma_1}^2 - 2\rho\frac{x_1-\mu_1}{\sigma_1}\frac{x_2-\mu_2}{\sigma_2} + \frac{x_2-\mu_2}{\sigma_2}^2])} \qquad \text{(Equ:3.11)}$$

Here μ_1, ρ_1 are the mean and variance of the image with first features and μ_2 , ρ_2 are the mean and variance of the image with the second features, ρ is called the shape parameter such that $-1 = \rho_i = 1$.

3.3.3 Ultrasonic sensor based staircase detection

While the image based method alerts the presence of upward or downward staircase, precise control is needed for actual navigation through the staircase. In order to assist the visually impaired during the identification of staircase, we employ two ultrasonic sensors that can

distinguish horizontal floor planes and variation of depth of these planes in case of downward staircase and presence of vertical plane in case of upward staircase. This system is built using a PVC plastic and the ultrasonic sensor which captures the signals in the form of a frequency curve, this system is developed by using an Arduino processor which acts as a processing unit for better identification. A Bluetooth device is also associated with the device so that the data can be captured and communicated to a mobile device that can provide auditory feedback in conjunction to vibro-feedback driven by the Arduino board.

3.4 Experiment

The developed stick can be more helpful to the visually impaired to navigate safely both indoor and outdoor. It yields excellent results in sensing the obstacle on the path of the user up to a range of three meters. The key features of the proposed system are low cost, reliability, and portability. Despite the fact that the system is equipped with sensors and other components, the PVC stick utilized for this work weighs around 600 grams. During the experimentation process, it is observed that, whenever the sensor identifies a hollow signal, sensor gets activated and generates an audio signal announcing that a manhole is ahead. The experimentation is repeated using GMM also and the results are depicted in the Figure 4.2. The procedure is repeated in case of identification of staircases and in this case, BGMM is considered and basing the Maximum Likelihood criteria, the ascending or descending staircases are identified and the subsequent alerts are generated.
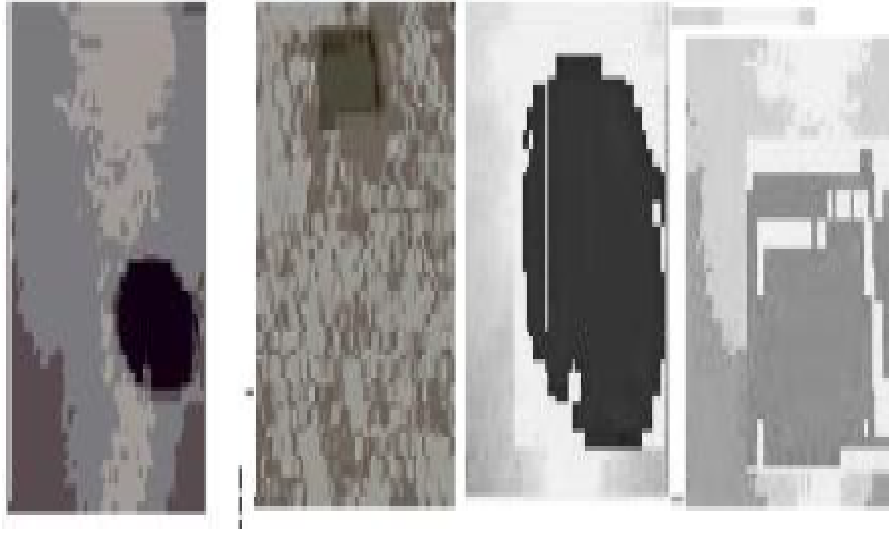

Figure 3.11: Inputs of manholes

Figure 3.12: Segmented outputs of manholes using GMM

ows the performance of manhole detection. Figures 4.1 and figure 4.2 illustrate the scenarios where manhole is successfully detected from various angles and corners. It can be observed from the results that the false positive rate and false negative ratio values are very less, which signifies the efficiency of the proposed development.

The confusion matrix results indicate that the model exhibits a high sensitivity and
specificity of 0.89 and 0.92 respectively; such performance makes the model suitable for a high detection rate with a very low error rate. In Table 4, Green Region indicates True Positive, Orange Region= False negative Brown Region = False positive, and Violet Region indicates true negative.

For staircase detection based on Bivariate Gaussian Distribution, our training set consists of 74 downstairs, 82 upstairs, and 62 negative training samples. These are randomly collected samples which are selected for subset classification. For the purpose of testing, we have considered 52 downstairs, 40 upstairs, and 46 negative samples, in total 138 samples were considered for the classification purpose. We have tested for estimating the accuracy of the classification model with respect to ascending and descending staircase recognition and also the efficiency in differentiating the ground and non-ground planes, the results derived are presented in Table 5. These results showcase the performance of the system in recognition of stair cases and suggest that this method can be practically implemented in the real world situations. Figures 4.5-4.7 depict the results of staircase detection.

Our work shows precision of 93.7% for ascending staircase and 82% for descending staircase as compared to 84% of the stereo image based methods. Similarly our manhole detector shows a precision of 92.5% as compared to 80% for image based manhole detection
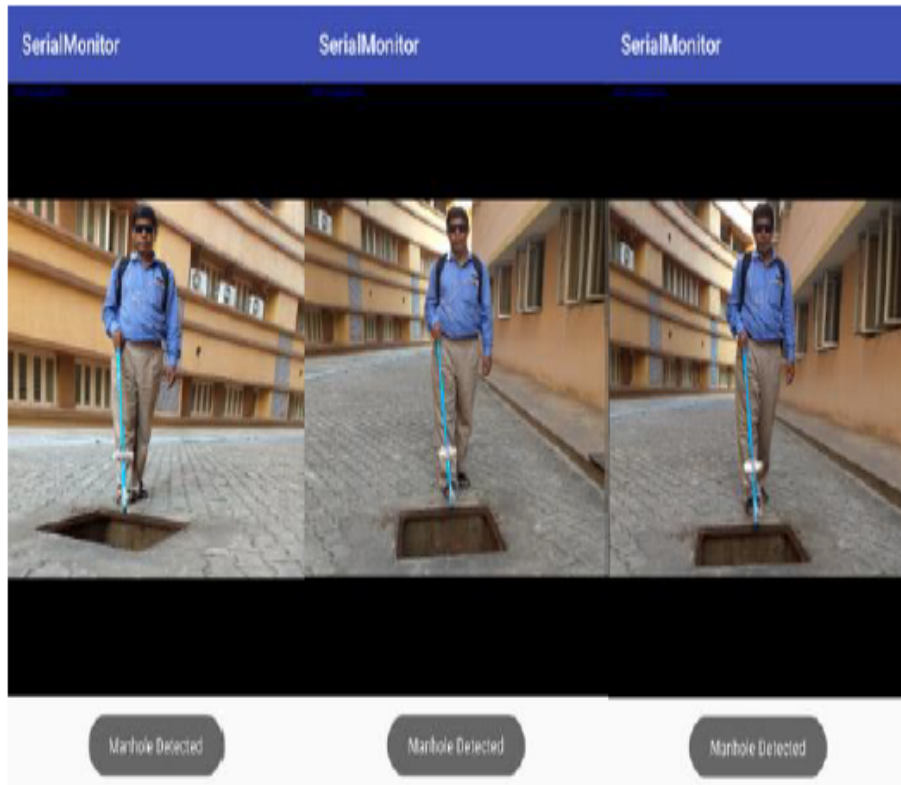
Figure 3.13: Manhole detection using the sensors mounted on the stick

presented.

CONFUSION MATRIX		OUTPUT	
		Manhole	Not Manhole
INPUT	Manhole	92.50%	7.50%
	Not Manhole	11.70%	88.30%
Accuracy			0.90
Precision			0.93
Recall / Sensitivity			0.89
Specificity			0.92

Figure 3.14: Table 4:Manhole detection results

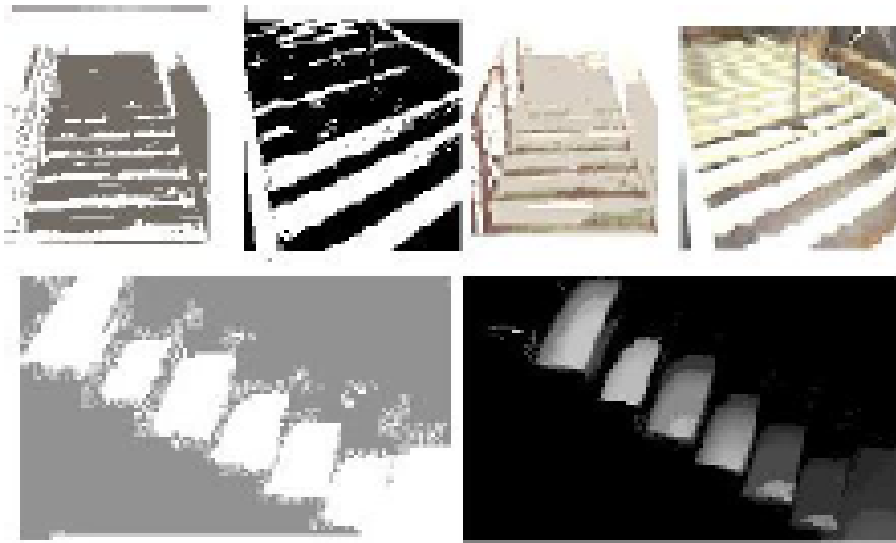Figure 3.15: Inputs of upward and downward staircase

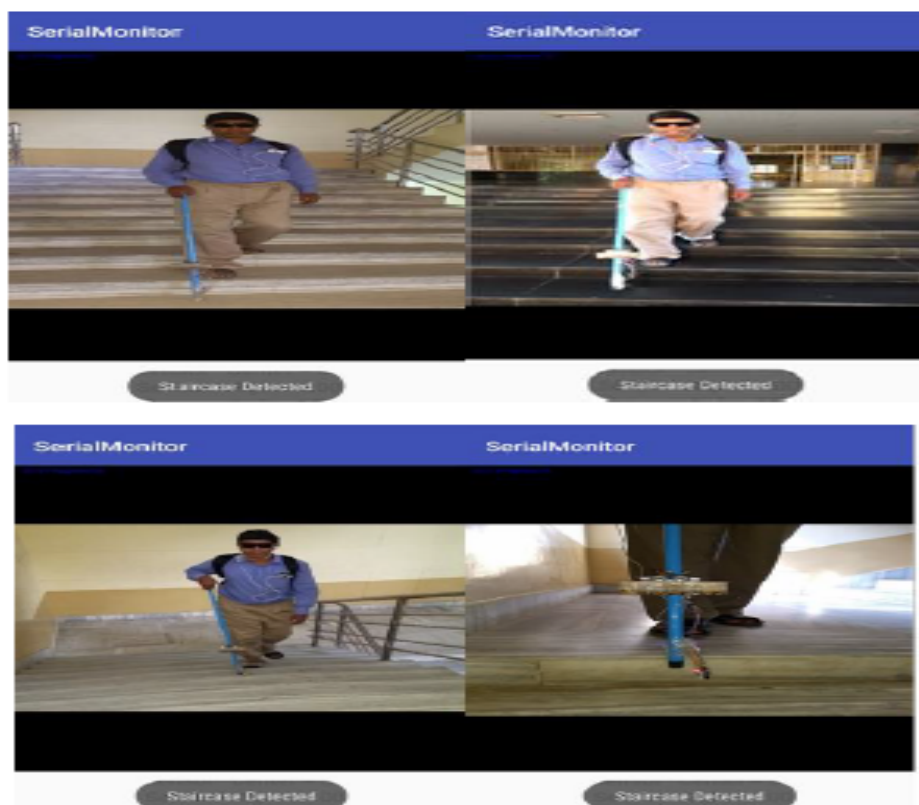Figure 3.16: Segmented Outputs of Staircases using BGMM with SURF Features

Figure 3.17: Staircase Detection using Stick. Descending Staircase (top). Ascending Staircase (bottom)
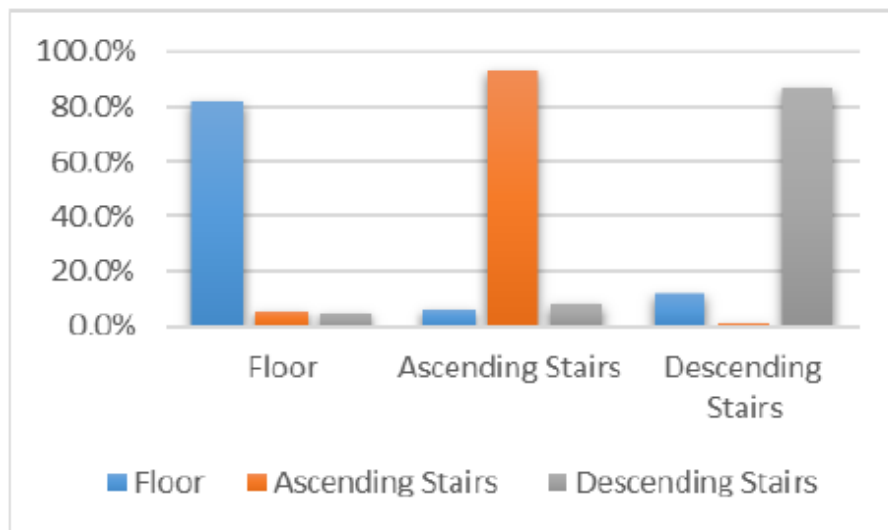
Figure 3.18: Performance of Staircase Detection in Percentage.

Conclusion

The principal objective of this paper was to build up a low-cost prototype of a stick for visually impaired persons, for helping them in proper identification of manhole and staircases. In this article, a novel work is presented for the identification of the manholes and staircases for the visually impaired people using threshold-based system from data obtained through unique arrangement and placement of ultrasonic sensors for effective identification of manholes and staircases. We also trigger image based method to determine median based threshold value for identifying manholes using Gaussian Mixture Model. Furthermore, we present novel way of extracting features using SURF algorithm identification of ascending/descending staircases based on Bivariate Gaussian Mixture Model. The hybrid model not only informs the presence of manholes/staircases but also helps navigate them by real time vibration and audio alert feedback. The proposed device has been shown to work well within the budget and has achieved its major objectives – to be affordable and simple.

The developed model complemented by using the metrics like Threshold based, Precision, Recall, and F-Measure showcase good recognition accuracy. These results indicate that this method can be practically implemented in the real world situations.

The recognition accuracy of the developed models is tested against distance estimation and recognition towards the identification of ascending and descending staircases. The performance varies when we are facing an ascending staircase or a descending one. Due to the direction of the sensor, standing before a descending staircase permits us to have an overview of the entire staircase, however, due to the self-overlapping of successive steps, there will be some deviations with respect to the measurements.

Relatively, in case of ascending staircases, the proportion of uncovering reduces, since the steps stay very much close to the individual during mounting the steps and hence the recognition rate increases.

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