iSight:Computer Vision and Ultrasonic Sensor based Smart Cane and Glasses for Visually Impaired People

2015-FYP-03

Submitted by:

Hadia Nadeem 2015-EE-052

Ayesha Khurram 2015-EE-101

Syed Murtaza Arshad 2015-EE-116

Ayesha Rehman 2015-EE-159

Supervised by: Dr. Ubaid Ullah Fayyaz

Department of Electrical Engineering

University of Engineering and Technology Lahore

iSight:Computer Vision and Ultrasonic Sensor based Smart Cane and Glasses for Visually Impaired People

Submitted to the faculty of the Electrical Engineering Department
of the University of Engineering and Technology Lahore
in partial fulfillment of the requirements for the Degree of

Bachelor of Science

in

Electrical Engineering.

____________________	____________________
Internal Examiner	External Examiner

____

Final Year Project
Coordinator

Department of Electrical Engineering

University of Engineering and Technology Lahore

Declaration

I declare that the work contained in this thesis is my own, except where explicitly stated otherwise. In addition this work has not been submitted to obtain another degree or professional qualification.

Signed: ____________________

Date: ____________________

Signed: ____________________

Date: ____________________

Signed: ____________________

Date: ____________________

Signed: ____________________

Date: ____________________

Acknowledgments

First and foremost thanks to Allah Almighty for helping us choose, design and implement our idea. We would like to thank our Advisor, Dr. Ubaid Ullah Fayyaz for guiding us and providing us with suitable workspace. We would like to thank our chairman Dr. Khalid Mehmood Ul Hassan and our co-advisor Dr. Kashif Javed for helping us with this idea. We would also like to thank Dr. Syed Abdul Rahman Kashif for allowing us to participate and display our project at different competitions and universities. Thanks to our loving parents for their support in tough times. Special thanks to Mr. Ali Hassan, a legally blind UET employ for helping us testing and improving this project. Last but not the least, We would like to thank our department and whole working staff for their help in arranging instruments and documents to complete this project, we are indebted to you for everything.... . .

Dedicated to our parents. . .

Contents

Acknowledgments iii

List of Figures viii

List of Tables ix

Abstract x

1 Introduction 1

1.1 Motivation . . . 1
1.2 Problem Statement . . . 2
1.3 Proposed Solution . . . 3
1.4 Beneficiaries of Project . . . 4
1.4.1 Blind Community . . . 4
1.4.1.1 Complete Blindness . . . 5
1.4.1.2 Color Blindness . . . 5
1.4.1.3 Night Blindness . . . 5
1.5 Visually Impaired People . . . 5
1.6 Catering Third World Countries . . . 5
1.7 Research and Development . . . 6

2 Review of Literature 8

2.1 Literature for Smart Cane . . . 8
2.1.1 Smart Cane in 2010 . . . 8
2.1.2 Smart Cane in 2014 . . . 8
2.1.3 Smart Cane in 2015 . . . 9
2.1.4 Smart Cane in 2016 . . . 10
2.1.5 Smart Cane in 2017 . . . 10
2.2 Literature for Smart Glasses . . . 11
2.2.1 Smart Glasses in 2013 . . . 11
2.2.2 Smart Glasses in 2015 . . . 11
2.2.3 Smart Glasses in 2016 . . . 12
2.2.4 Smart Glasses in 2017 . . . 12
2.3 Outcomes of Literature Review . . . 12

3 Methodology 14

3.1 Obstacle Detection Algorithm . . . 14
3.2 Navigation and Decision Making . . . 17
3.3 Face Detection Algorithm . . . 17
3.4 Face Recognition Algorithm . . . 19
3.5 Water Level Smoke Detection Algorithm . . . 20
3.6 Flow Diagram . . . 21

4 System Architecture and Design **22**
4.1 Complete System . . . 22
4.2 Input Subsystem . . . 23
4.2.1 HCSR04 Working . . . 23
4.2.2 Camera Module V2 . . . 24
4.2.3 Smoke Sensor MQ-2 . . . 24
4.2.4 Water Sensor Module . . . 25
4.3 Processing Subsystem . . . 25
4.3.1 Switch and Microcontroller . . . 25
4.4 Output Subsystem . . . 25
4.4.1 Earphones and Vibrator Motors . . . 25
4.5 Implementation . . . 26
4.5.1 Data Acquisition . . . 26
4.5.1.1 Filtering Array . . . 26
4.5.1.2 Video Stream Processing . . . 27
4.5.1.3 Analog to Digital Conversion . . . 27
4.5.2 Interrupt Configuration . . . 27
4.5.3 Output . . . 27
4.5.3.1 Audio Output . . . 27
4.5.3.2 Haptic Feedback . . . 28
4.6 Product Design Process . . . 28
4.6.1 Design of Smart Cane . . . 28
4.6.2 Design of Smart Glasses . . . 29

5 Results And Discussion **31**
5.1 For Smart Cane . . . 31
5.1.1 Obstacle Detection . . . 31
5.1.1.1 Response Time . . . 31
5.1.1.2 Range . . . 32
5.1.1.3 Accuracy . . . 32
5.1.2 Depth Measurement . . . 33
5.1.2.1 Response Time . . . 33
5.1.2.2 Range . . . 33
5.1.2.3 Accuracy . . . 34
5.1.3 Staircase Detection . . . 34
5.1.3.1 Response Time . . . 35
5.1.3.2 Range . . . 35

5.1.3.3 Accuracy . . . 35
5.1.4 Water/Puddle Detection . . . 36
5.1.4.1 Response Time . . . 36
5.1.4.2 Range . . . 36
5.1.4.3 Accuracy . . . 36
5.1.5 Smoke Detector . . . 36
5.1.5.1 Response Time . . . 37
5.1.5.2 Range . . . 37
5.1.5.3 Accuracy . . . 37
5.2 For Smart Glasses . . . 37
5.2.1 Face Detection . . . 37
5.2.1.1 Response Time . . . 37
5.2.1.2 Range . . . 37
5.2.1.3 Accuracy . . . 38
5.2.2 Smile Detection . . . 38
5.2.2.1 Response Time . . . 38
5.2.2.2 Range . . . 38
5.2.2.3 Accuracy . . . 38
5.2.3 Face Recognition . . . 39
5.2.3.1 Response Time . . . 39
5.2.3.2 Range . . . 39
5.2.3.3 Accuracy . . . 39
5.2.4 Object Detector . . . 40
5.2.4.1 Response Time . . . 40
5.2.4.2 Range . . . 40
5.2.4.3 Accuracy . . . 40

6 Conclusion **42**

References **43**

List of Figures

1.1 Minion 2

3.1 Obstacle detection process flow 15
3.2 Obstacle Detection and Height measurement using Ultrasonic Sensors . . . 15
3.3 Upstairs Detection using Ultrasonic Sensors 16
3.4 Depth measurement and downstairs detection using Ultrasonic Sensors . . 16
3.5 Navigation testing on Python shell 18
3.6 HAAR features 18
3.7 HAAR features on human face 19
3.8 Face recognition process flow 20
3.9 Water/Puddle detection 21
3.10 Flow diagram of methodology 21

4.1 Block diagram of complete system architecture 22
4.2 Sensors arrangement on cane 23
4.3 Outlook of smart glasses 24
4.4 Microcontroller inside cane module 26
4.5 Product Design Process 28
4.6 Design of smart cane 29
4.7 Design of smart glasses 30

List of Tables

5.1 Confusion matrix for array filter of size 3 of Obstacle detection 33
5.2 Confusion matrix without array filter of Obstacle detection 33
5.3 Iterated Experiments for Depth Measurement 34
5.4 Confusion matrix For Upstairs case detection 35
5.5 Confusion matrix For Down Staircase detection 36
5.6 Confusion matrix For Face detection 38
5.7 Confusion matrix For Smile detection 38
5.8 Confusion matrix For Facial Recognition 40
5.9 Confusion matrix For Object Detection 41

Abstract

iSight is a state-of-the-art device which helps blind people in daily life to overcome navigation and identification issues. This smart device consists of glasses and cane with audio guidance. The smart cane assists a person in navigating from one place to another, without any hindrance by detecting obstacles from front, left and right. The user can also detect depth of potholes and height of obstacles. It also supports water (puddle) detection and smoke detection. It uses decision tree algorithm for path navigation. This algorithm uses the information coming from US sensors to devise a probable path for the subject. Smart glasses provide a system for facial detection, recognition and object identification. For the face recognition system, a minimum of 10 pictures of a personâs face are required for training the deep neural network. Next time that person comes in front of the camera, he will be instantly recognized. Glasses, can also detect how many people are present in front of that person as well as the expressions of the person in front of him. The device is also trained to identify daily life objects. The final product will support multiple modes of operation so blind people can control these features with respect to their needs. This device is completely portable and rechargeable. It is a low-cost device which will commendably enhance the userâs travelling experience as well as his/her interaction with people and objects in indoor environment, making them independent to a great extent…

Chapter 1

Introduction

To facilitate physically disabled people has always remained a task for researchers and engineers. A lot of work has been done on assisting people who carry disability of any form. Efforts have been made to nullify the effects of disability in the most efficient ways. One such area that has received much attention is to develop a blind assistant. Therefore, a lot of work has been done to help the blind and visually impaired people in order to guide them and enable them to live an independent and normal life but there are still some areas that remain unexplored. Our aim is to develop an integrated smart device that can help visually impaired people to make their lives easier, better and a bit less demanding.

1.1 Motivation

World Health Organization (WHO) estimates that in 2010 there were 285 million people visually impaired, out of which 39 million were blind [1]. According to a study, Sub-Saharan Africa and South Asia have the highest percentage of blind older people world wide [2]. National Committee for the Prevention of Blindness (NCPB) states that there are 1.14 million blind adults in Pakistan (2003 statistics) [3].

According to the Journal of Pakistan Medical Association, the blindness rate in Pakistan varies from 2.0% to 4.3%, which makes up more than 2 million people [5]. The most common causes of of blindness in Pakistan includes cataract (66.7%), corneal opacity (12.6%), refractive errors(11.4%), glaucoma(3.9%) and others(5.4%). Across the country, 58.47% of the blind population is concentrated in Punjab, 26.24% in Sindh, 10.26% in KPK, 4.65% in Balochistan and 0.38% in FATA [6]. Considering all these statistics, if we have a look at the facilities that are available to the blind community is Pakistan, then they are nil. They face a lot of problems in their routine tasks, in navigating, moving around and identifying objects and people. They are constantly depending on others for

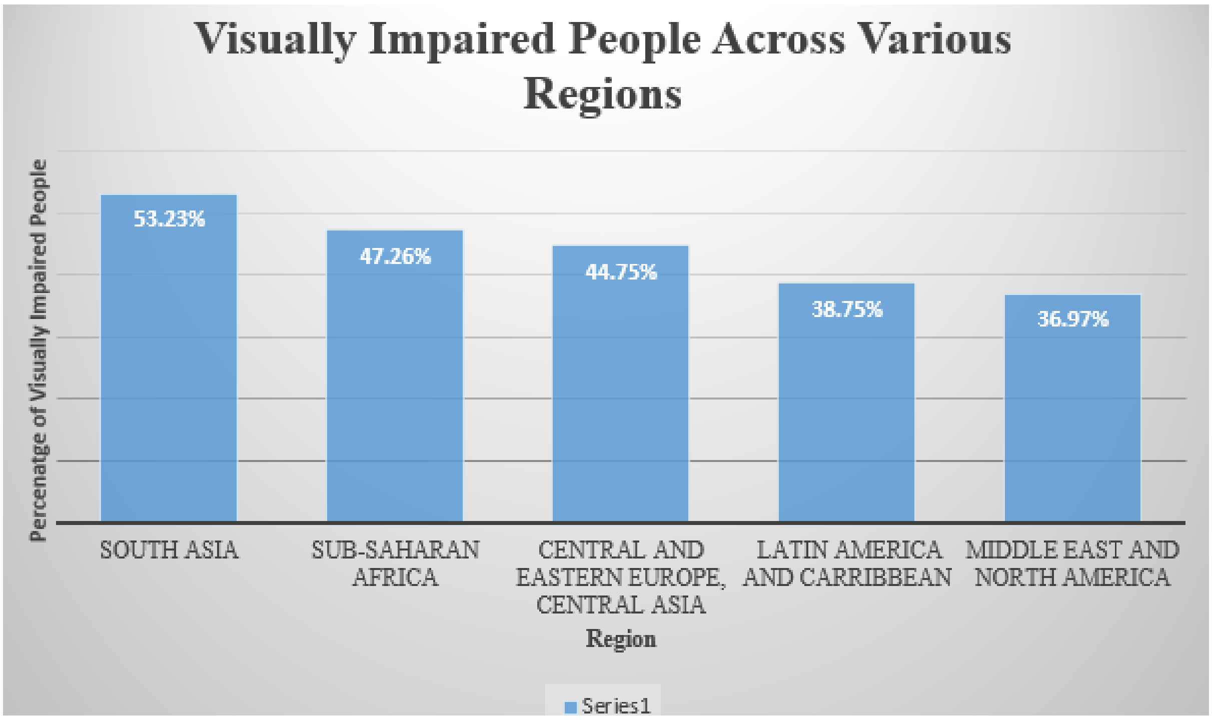

FIGURE 1.1: Vision Impairment Percentage in Different Regions[4]

support and guidance. They make up a huge percentage of Pakistanâs population, but due to their inability to work and earn something, they remain as a constant burden on countryâs economy.

However, for solving the problems of blind community, some products have been introduced in foreign markets such as WeWalk[7], BAWA[8] and UltraCane[9]. WeWalk provides the basic feature of obstacle detection, voice navigation and connects wirelessly to the smartphone. Whereas BAWA and UltraCane also provide obstacle detection and pairs with the smartphone. The above mentioned products usually cost around $500 or more, which is extremely expensive for a Pakistani layman and blind community of other third world countries. If we take into account all the above mentioned facts and figures, we come to the conclusion that in international market, no such product is available at low cost for the blind community that utilizes modern technology to solve their problems and ease their lives. In such circumstances, a cheap blind assistant is needed in the market that makes use of latest technology to deliver features that can help the blind in navigating and identifying objects which can help reduce their dependency on others and hence boost their confidence.

1.2 Problem Statement

Blind people find it difficult to move around, avoid obstacles, identify people and categorize different objects. Simple wooden or plastic white sticks have been the most

rudimentary aid for the visually impaired to maintain their balance, detect obstacles and find a safe path. They also use shaded glasses to protect their eyes from light and physical dangers. But with increasing transport, construction and buildings, white sticks are becoming less effective in outdoor areas. Number of pedestrian casualties are increasing, so it is necessary to increase spatial awareness for the visually impaired. With growing technology electronic components are being used to upgrade these aiding objects to smart level so they can help the blind to enhance their awareness of surroundings and perform tasks safely and efficiently. In this age, a number of smart canes and smart glasses are available. Smart canes use different sensors such as IR, Ultrasonic, laser etc. to detect obstacles. Smart glasses use cameras for face detection and identification of objects.
There have been many other attempts separately for smart cane and glasses in past to make these technologies available for the visually impaired in most comfortable and cost-effective way. There has not been a combined effort for smart cane and glasses linked together to serve the visually impaired in such a way that we can provide them comprehensive awareness of the surroundings. In this project, for the visually impaired person, our aim is to present a product comprising of Smart Cane and Smart Glasses for obstacle detection, staircase detection, face detection, object identification, water/puddle detection, smoke detection and voice control along with audio guidance. Smart cane will use different sensors to detect distance and height of obstacles along with depth of potholes. Smart glasses will use camera for person identification and object identification. A microcontroller will be used to integrate data from sensors and camera, process the information collected and provide guidance to the blind in the form of an audio output. Earphones will be used for the sake of providing audio guidance to the user.. The proposed product will be energy efficient, rechargeable, lightweight, portable and cost effective. Through the use of the proposed device, the blind will be able to buy things, recognize people and move around safely. Also, the effort and risk taken by visually challenged people during navigation can be greatly minimized.

1.3 Proposed Solution

The proposed system is basically an embedded system integrating the following components: a set of ultrasonic sensors, a pi-camera, smoke sensor, water sensor with microcontroller Raspberry Pi 3 B+. In the proposed work, a low-cost yet durable and accurate smart stick with smart glasses has been developed which holds the following characteristics:

- The smart stick can detect obstacles present in the path of blind and provides navigation

- The smart stick can also determine the height of object as well as the depth of pothole.
- The stick is designed to detect distance of front obstacles, right obstacles and left obstacles
- The cane also guides the user in climbing staircase up and down
- The user is also informed about the presence of water puddle, fire, smoke or combustion gases
- Smart glasses can perform face detection and tell if that person is smiling
- Facial recognition can also be done using smart glasses
- Glasses can also be used to detect and identify different objects present in the surroundings

Various inputs in the form of sound, distance, images and surface e.g. water, grass etc. are received from the surroundings via sensors. Sensors are sophisticated devices particularly designed to receive a very particular form of data from the surroundings. For example, ultrasonic sensors reflect and receive ultrasonic waves thereby help us in detecting obstacles and finding distances. An 8 MP camera takes live frames of the view. Each sensor has its own working principle. The data collected is then processed by the micro-controller using computer vision and artificial intelligence based algorithms and the user is guided to act accordingly.

1.4 Beneficiaries of Project

This project affects the community in various ways. It has a number social and economic impacts on the society. Besides being a blind assistant and helping the blind in various tasks, it also opens vast horizons of research and development. Moreover, the end product is a low-cost device that will help in catering the third-world countries. Following are some of the beneficiaries of the project:

1.4.1 Blind Community

People who stand entirely blind or else have partially impaired vision, have a problematic time in navigating outside. Indeed, physical movement is the major challenge for blind community. Travelling or just only walking down a congested or crowded path can be a challenging one. Also, blind person have to memorize the position of every single obstacle or item in their home and their daily surrounding environment.

Blindness normally means comprehensive deficiency of functional vision. Vision is basically the outcome of light rays hitting the back of eye then retina and then reaching the optic nerves which transmit electrical signals to the mind. Blindness happens when an insufficient amount of light reaches the retina and the information has not been transported to the mind properly. There are several different types of blindness prevailing in the society:

1.4.1.1 Complete Blindness

Complete blindness means loss of vision and inability to see anything entirely. It may be temporary or permanent. Blindness can be a result of damage to any portion of eye or optic nerves. Numerous different infections can be a reason of complete blindness as well.

1.4.1.2 Color Blindness

People who suffer from color blindness are called âdyschromatopsiaâ. Such people are unable to differentiate between colors. According to Merck Manuals reports, the most common form of color blindness is red-green color blindness, which makes it difficult to distinguish between certain shades of red and green.

1.4.1.3 Night Blindness

Night blindness is the vision deficiency that take place at night or when light is dim or when darkness takes place. It is not as intense as complete blindness but the person suffering from night blindness still needs some guidance and support in darkness.
Blind community is one of the major beneficiaries of our project. The device will help the blind in routine tasks: in navigating, detecting obstacles, recognizing people and identifying objects. It is an attempt to make their challenging lives a bit less challenging.

1.5 Visually Impaired People

Visually impaired person is the one suffering from partial or complete blindness. Partial blindness means reduced ability to see that cannot be corrected by wearing glasses or by any other means. The target audience of this device includes every kind of visually impaired person.

1.6 Catering Third World Countries

There are numerous facilities available across the globe for people suffering from blindness. In developed countries, special attention is paid to ease the lives of physically challenged people by facilitating them in their routine tasks. One such effort is tactile paving. It is an arrangement of textured ground surface indicator present on footpaths, staircases, pavements and railway platforms to assist pedestrians who are visually impaired. But unfortunately, we live in a society where there are zero facilities available to physically

disabled people. We canât even build footpaths that can ease the movement of handicapped people.
There are also different devices available that makes use of modern technology to form a blind assistant. One such device is âWeWALKâ. It is a smart cane for visually impaired people intended to help them in navigation. Itâs features are listed as follows:

- Obstacle detection
- Smartphone integration

The device usually costs around $500. Another such device available in the market is âBAWAâ. It too provides:

- Obstacle detection
- Voice navigation
- Connects to the smartphone

The selling cost of this device is $699. Moreover, âUltracaneâ is another product with similar features and costs around $827. These products are very expensive and are not affordable by blind community present in third world countries like Pakistan. Our device on the other hand provides a cheap alternative. It is a smart integrated device with advanced features and is also easily affordable. Itâs manufacturing cost lies in the range of PKR 15,000 - PKR 20,000. This device will be catering blind community present in third world countries, providing a cheap device that they can easily afford.

1.7 Research and Development

For making the life of blind people a bit easier and providing assistance to visually impaired people, there are some devices available in the market. Devices like Service Dogs, Canes and Electronic Mobility Aids etc are present in the market that are being used by the blind community. Service dogs are the dogs that are expert and trained to assist their owners by means of a specific infirmity. But as we know that dogs can be trained up to a certain limit to pick things up and so it is not really an effective way to provide assistance. Moreover, electronic mobility aids are also available in the market. These devices help user in detecting obstacles. As soon as an obstacle is detected, blind person gets a warning through an audio signal or through vibrators. Furthermore, with the advancement in technology, different smart glasses have also been introduced in the market that provide features like object identification, facial recognition etc.
Putting everything in a nutshell, there are such devices available in the market which

are providing features like navigation, face detection, identification any many more. But because these features are very diverse, they have not been yet combined or put together in a single product. Our product is an effort to realize a smart integrated device that has all the above mentioned features incorporated in a pair of smart cane and smart glasses.

- We have researched the problems by interviewing blind people and have added new feature accordingly combined with the existing features.
- We are using ultrasonic sensors and a servo motor to detect staircase pattern and classify them as either up or down stairs.
- In this context, no previous work has been done previously.
- No work has been done previously on detecting the height of obstacles and depth of pothole.
- It will be the first novel product featuring both smart cane and smart glasses.
- We intend to surpass the efficiency of previous models by filtering out bogus sensor readings and improving algorithms.

Chapter 2

Review of Literature

There exists a vast literature on blind assistant having different features in the form of smart cane or smart glasses. An extensive work has been done on both of them individually and on their characteristics in terms of reliability, power consumption, efficiency and appearance. In this project, we will be offering an amalgamation of both to provide the best eficiency and to include maximum features.

2.1 Literature for Smart Cane

Work is being done on making white cane for the blind more efficient that enables the user identify objects around it with little or no effort. In this review different forms of smart cane will be discussed in chronological order.

2.1.1 Smart Cane in 2010

One of the most rudimentary designs of smart cane was presented in [10]. It is a very basic device in which an ultrasonic sensor was mounted at the top of stick near handle. It used the readings of the sensor to measure the distance of the obstacle from the user. It has two modes of operation long range for outdoor and short range for indoor. The output is in haptic and vibrational form. The design of this device is very compact as the whole system is detachable from the stick and can be mounted on any normal cane. The biggest limitation this device has is that it can detect only front and knee-height obstacles. So, the blind will not be able to detect any obstacle from surroundings and which are below the height of sensor. However, this effort was the founding stone of many upgraded forms of smart cane with incorporation of other features.

2.1.2 Smart Cane in 2014

One form of smart cane was presented in 2014 in [11] which they proposed a smart cane connected with a smartphone. This cane provided features like: obstacle detection, navigation, audio guidance and immunity from sudden falls. It basically uses an ultrasonic sensor for obstacle detection. The sensor is connected to the AVR module. With the help of the signal received from the sensor the distance of the nearest hurdle is calculated. The output is communicated to the android phone via a Bluetooth module. Guidance is provided to the user through a speaker and three vibrators present on the cane whenever the distance of the obstacle becomes less than a certain threshold value. The speaker provides audio guidance for movement, whereas, the three vibrators vibrate and tell whether the obstacle is present towards left, right or at the front. The cane presented is an efficient and effective method for obstacle detection but there is no way of identifying the height and distance of the obstacle from the user. Also, this cane cannot detect the pits or trenches present in the path and cannot identify stairs.

2.1.3 Smart Cane in 2015

Another form of smart cane was presented in [12]. The distinctive quality of this cane is that it used infrared sensor instead of ultrasonic sensors. It uses two infrared sensors, one horizontal and one inclined. The horizontal one is mounted on the top for obstacle detection, whereas, the inclined one in mounted below the horizontal one for staircase detection. The cane can differentiate between stairs up and stairs down by the shape of the wave being reflected by the obstacle and received by the receiver. The information from the sensors goes to the PIC micro-controller. The controller calculates the distance of the obstacle. If this distance is less than the threshold, vibrator produce vibrations to inform the user. Audio guidance is also provided using ISD 1932. It is multiple message recording and playback device. It plays the audio message according to the input it receives and communicates it to the user via earphones. The cane presented is cheap, light weight and has fast response and long battery life. The most prominent feature of this device is staircase detection and its direction. This is done via inclined infrared sensor. The signal received in case of upstairs and downstairs has different amplitude range. By identifying this range, the direction of the staircase in determined. The micro-controller can also determine the distance of stairs from the blind by calculating the variations of the signal received as the blind walks towards the stairs. Despite of all the features this cane provides, it has one very prominent drawback as well. When a person is moving, the obstacle can be present in front of the sensor or on the floor. The obstacle present in front of the sensor is easy to detect but the one lying on the floor cannot be easily detected using this cane. Also, this project can be further improved by connecting it with an android phone for some additional features.

2.1.4 Smart Cane in 2016

[13] incorporated many other features along with obstacle detection. This device uses three ultrasonic sensors for obstacle detection from front, left and right side. Another, fourth ultrasonic sensor is used to measure the depth of the pit in front of the user. This depth sensor is mounted at bottom at an angle of 25 degrees so that it can detect depth from a considerable range. It uses water sensor module to measure the level of water of the path of the blind person, in order to avoid the slippery floors and puddles. The output is in form of different vibratory motors mounted on handle of the cane. The microcontroller used is ATMega 2560. The distinct feature of this design is that it has a GSM module connected to it. With the help of this GSM module the blind user can send his/her location to relatives by pressing a single button the stick in case of emergency conditions. The limitations of this is model are that it has an ultrasonic sensor mounted at an angle to measure the depth of the pit in front. But the problem with this design is that the ultrasonic waves move straight with deviation of few degrees. Due this fact the accuracy of depth measuring sensor is not up to the mark. Also the output of all the features is in vibratory patterns, due to which the user has to learn a large number of patterns to recognize the output. Another drawback this device faced is that it can only determine the presence of an obstacle but not measure the accurate distance from the user.

2.1.5 Smart Cane in 2017

These problem was tackled in 2017 in [14]. It uses multiple sensors for obstacle detection of different heights and distances. It has the following features.

1. Detects knee-below and knee-above height obstacle
2. Uses multiple ultrasonic sensors for upwards and downwards staircase
3. Wireless earphones for guidance
4. Exact distance of obstacle is communicated to the user

This project is not cost effective as it uses multiple sensors for detecting obstacles. All the projects presented, work on the same basic principle. They use a sensor to measure the distance of the nearest object and if that distance is less than the threshold value, they inform the user. Our aim in this project is to achieve these goals and to present the most efficient and cost effective cane with maximum number of features.

2.2 Literature for Smart Glasses

The idea of smart glasses is not very old. Their structure and features are still in development phase. A few available products in market such as Google Glass, Vuzix Bladea and Vue are just augmentations for normal eye, they are not for aiding blind people. Smart glasses for blind are still center of focus of researchers to provide blind people as much aid as possible, thus creating virtual sight.

2.2.1 Smart Glasses in 2013

[15] is one of early attempts on smart glasses. They worked on one of the major problem of working with live streams and moving frames which is blurred frames. These smart glasses uses support vector machines to differentiate between blur and clear images. Feature extraction is used to detect edges of images. It is found that blur images have wider edges than clear images. After detecting blur images an image clearing algorithm is used. The main feature of these glasses is text recognition. The output is provided in audio form which helps the blind to read normal text in outdoor as well as indoor environment.

2.2.2 Smart Glasses in 2015

In 2015, a face recognition System for blind was proposed in [16]. It uses a camera fixed on the glasses. The output is delivered through vibrating motors attached on a stick with a mobile computer. This computer performs feature extraction and does face detection using Adaboost. The cane was equipped with a Bluetooth module and receives data from mobile computer. The vibration motor then produces different types of vibration for different persons by simply varying the duty cycle of PWM wave. The system has reduced the computation complexity and improved the speed by using compressed sensing with l2- norm as a classier. The success rate was 93%. However, it only includes a single feature of face recognition.

Further in 2015, another group proposed a similar kind of solution for face recognition and detection as given in [17]. The major difference in it was its physical appearance. This design is a kind of optical head mounted display (OHMD). It uses a camera and handsfree as an input and output respectively. The device uses parallel pipeline technique to reduce latencies of the process. The system architecture of the application uses multiple threads. The main thread is used to acquire camera image and provides interface for interaction. A background thread is used for constant processing stream of frames obtained from the main thread. If the algorithm detects a face then it searches and compares it with current database for recognition. The face detection process is speeded up by using cascaded classifier.. This algorithm divides the image frame in smaller window frames. At a time specific time only few windows are detected for faces. This reduces the amount of processing done to detect faces in an image.. The advantages of using this technique are that the load on processor is reduced, provides very fast face detection and provides real time face tracking. The usage of deviceâs GPU to implement conversion of format and resizing of images, reduced the time of computation about three times. In this way the consumption of energy in this whole process is reduced about five times. Hence, [17] proposed a solution which optimized the process of face detection using fast image processing algorithm which reduced the load on processor and increased the efficiency of device in terms of energy. However, it suffered a trade of between frame resolution and time of processing.

2.2.3 Smart Glasses in 2016

In 2016, another paper was published on the same idea of Facial Recognition proposed in [18]. They managed to recognize not only static faces but also identified faces in real time video streams. This device detects face using camera mounted on glasses (client). The captured frames are sent to a server (cloud) so that the face detection is fast and accurate by using a high processing power system. The client-server connection was wireless. It uses TCP/IP protocol to transfer images and data between client and server. The limitation in [10] was the battery life. This face recognition system was not energy efficient, which affected the battery life of glasses. The battery life of constant face recognition on InfoLinker was just 6 minutes, while for Moverio, battery life was 48 minutes.

2.2.4 Smart Glasses in 2017

Recently in 2017, a different type of smart glasses was proposed as discussed in [19]. It worked on the obstacle detection for the blind. The device included a glasses with a module for obstacle detection. The processor was also mounted on glasses. The output is provided in form of beeps and buzzers. Ultrasonic sensor was used as an obstacle avoiding module. If it finds an object in a range of 300 cm, it senses them and create sound. Distances greater than 3 meters are out of its range. The object distance was directly proportional to the beepers sound. It was simple, cheap in price and easily constructed device with a single feature and no complexity.

2.3 Outcomes of Literature Review

After reviewing the above literature on smart glasses for image processing and smart cane for obstacle avoidance it can be concluded that there are several methods to achieve these tasks and help the blind community. Each method has its own pros and cons. Two basic technologies which are the most suitable way to assist the blind are:

1. Ultrasonic sensor-based method
2. Camera based method

It is concluded that each proposal has its own advantages and disadvantages. An amalgamation of both devices will result in a device that combines all the best features using both camera and ultrasonic sensors, which is cost effective as well as energy efficient. The algorithms and techniques that will be used for obstacle detection and image processing will be discussed in next chapter.

Chapter 3

Methodology

3.1 Obstacle Detection Algorithm

One of the most basic and important feature of the smart cane is obstacle detection. The most crucial problem that a blind person faces is in navigation. They find it difficult to move around and detect obstacles. This problem is addressed in our project and rectified using a set of sensors. The requirement of this project is that we need such sensors which can efficiently detect obstacles present in its path and find the distance. For this purpose, we are using ultrasonic sensors. An ultrasonic sensor works by sending out ultrasonic waves. The sensor has a transmitter as well as a receiver. Ultrasonic waves are sent out through the transmitter and after reflection from the obstacle they are received by the receiver. The time is measured from the transmission of the wave to when the reflected wave is received and this time is then used to find the distance of the obstacle.

$$Distance = \frac{1}{2} * T * C \tag{3.1}$$

Where T is the total time between transmitting and receiving wave, C is the speed of ultrasonic waves and 1/2 is used to find the one way time of travelling wave. Using this formula, we find the distance of the obstacle and if that obstacle is present closer than the minimum threshold value that we have set manually, the user is informed of its presence.

There are plenty of other sensors available for obstacle detection as well like IR sensors, proximity sensors etc. But, ultrasonic sensors give us many advance features that others donât.

1. They can detect transparent objects that can not be detected by IR sensors as they are based on light transmission.

2. They are not affected by dust or moisture.

3. They can also be used to detect complex structured objects.

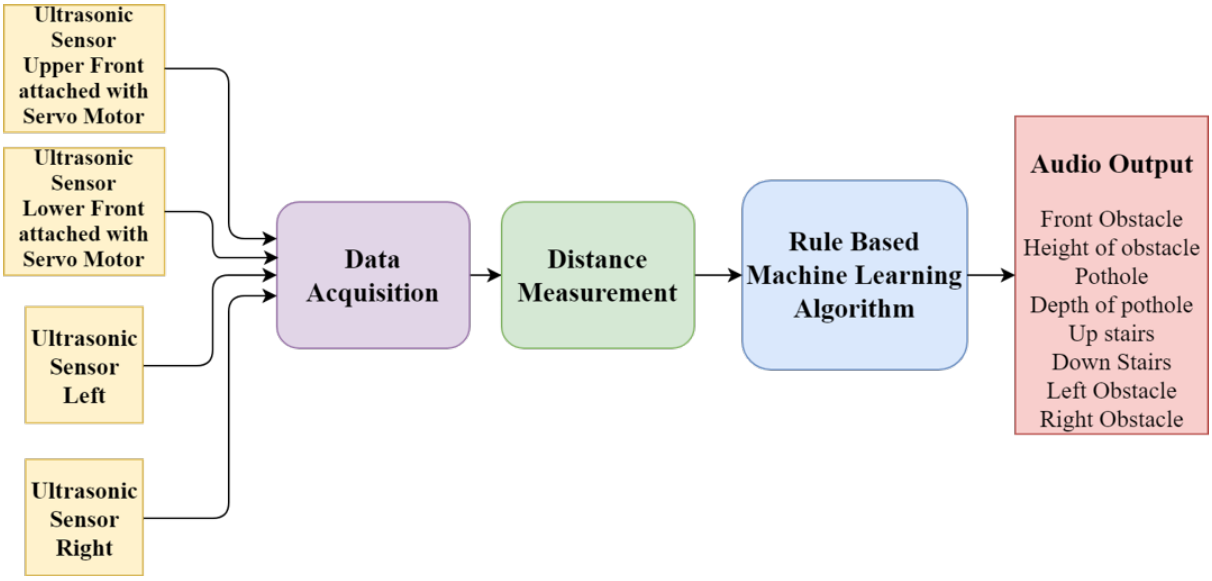

FIGURE 3.1: Obstacle detection process flow

Five Ultrasonic sensors will be placed on the cane at different positions. The first ultrasonic sensor will be attached through a servo motor at the front of the stick that can give complete 180 degrees of rotation. It will be primarily used to detect the front obstacles, staircase (up and down), height and distance of the obstacle. The distance of the obstacle will be calculated through the product of half of the time of the ray sent and received and the speed of the ultrasonic wave. Using this distance and the rotation angle, Pythagoras theorem will give the height of the obstacle as well as its distance from the user.

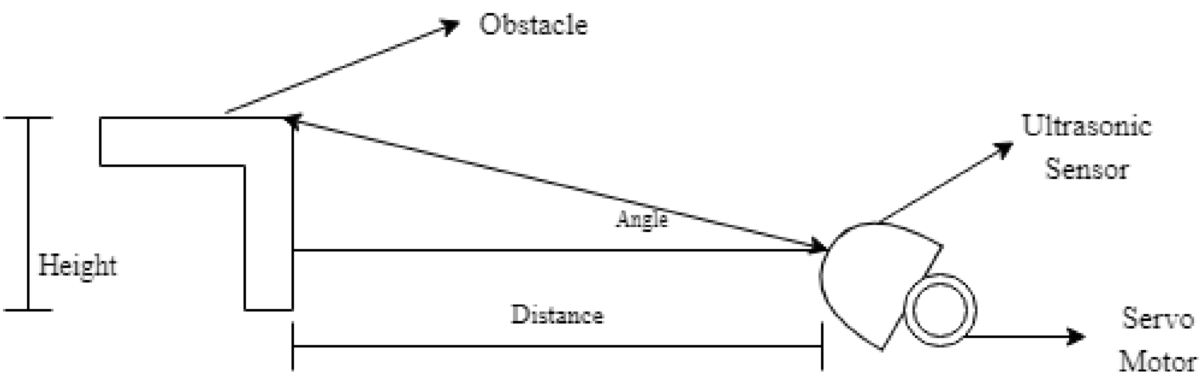

FIGURE 3.2: Obstacle Detection and Height measurement using Ultrasonic Sensors

For the detection of stairs, another sensor is placed 15 cm above the front sensor. The fact that the distance of the consecutive stairs is approximately double will be used to distinguish stairs from obstacles. So, if the distance returned by second sensor is double the distance returned by front sensor, then stairs are detected.

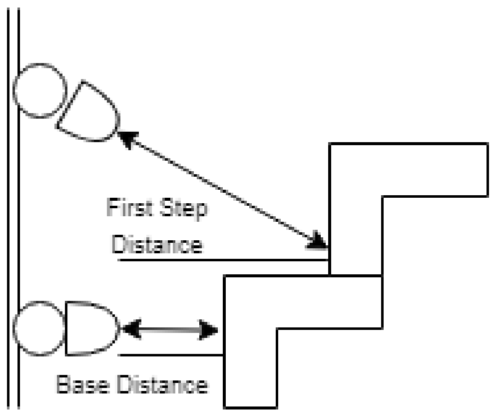

FIGURE 3.3: Upstairs Detection using Ultrasonic Sensors

The third ultrasonic sensor will be placed at left side of the stick which will help us in detecting left obstacles along with the distance. But assuming that the users hold the stick in their right hand, the legs wonât be detected as an obstacle. Left obstacle will be detected only if it is present beyond the legs of the user and for this we have set the threshold value manually. Similarly, fourth ultrasonic sensor will help us in detecting right obstacles and the fifth sensor will be used for depth measurement.

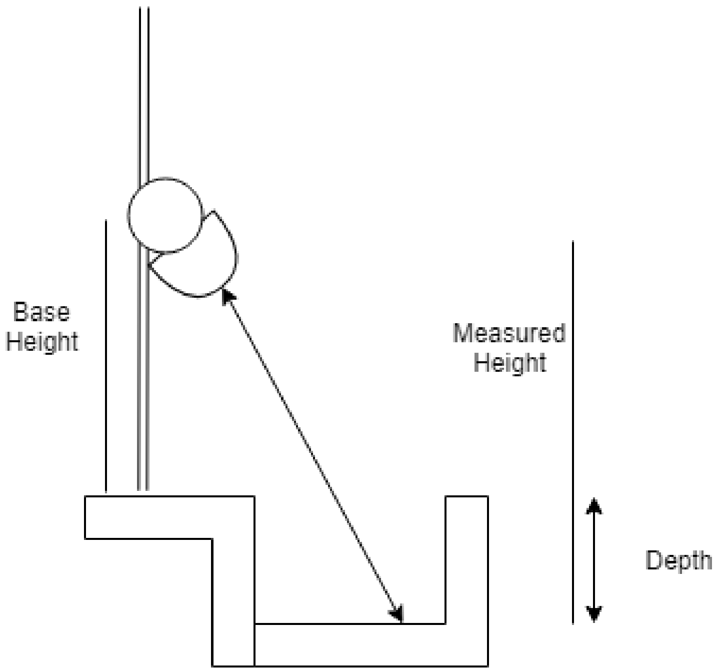

FIGURE 3.4: Depth measurement and downstairs detection using Ultrasonic Sensors

3.2 Navigation and Decision Making

After getting the data from sensors, the next step is to process this information using artificial intelligence algorithms and taking appropriate decisions to guide the user. For we use a decision tree algorithm. There are nine cases in total that the user can encounter:

- Pothole
- Staircase
- Front obstacle
- Right obstacle
- Left obstacle
- Front and right obstacle
- Front and left obstacle
- Left and right obstacle
- Front, left and right obstacle
- None

The depth sensor has the highest priority in all sensors. Whenever the depth sensor detects a depth greater than the threshold value, a pothole is detected. Next, the data from front, left, right and staircase sensor is gathered and one of the above listed cases is encountered. In case front obstacle is detected, we first check whether stairs are present or not. For this we say, if the distance measured by the staircase sensor is roughly double the distance measured by the front sensor, staircase is present. If not, the servo motor rotates and moves the front sensor to find the height of the obstacle. After finding the height, the user is then guided whether the obstacle can be stepped over or not. The user is then guided to move in the appropriate direction.

3.3 Face Detection Algorithm

HAAR algorithm is a color independent, fast and comparatively accurate image detection technique with low false-positive rate. HAAR object detection acts as a funnel where every region of an image is analyzed using a set of classifiers called HAAR features that act as a funnel called HAAR cascade. The classifiers at the top of the cascade are extremely fast and have low false negative rates to immediately remove regions of an

Figure 3.5: Navigation testing on Python shell

image that do not contain a face. Images are rejected as soon as possible if their features do not resemble a face. HAAR object detector works by calculating an integral image of a grayscale image similar to an integral over a function in calculus. Every pixel contains sum of the intensities of every pixel above it and to its left in the original image, allowing average intensity of every rectangular portion of an image to be obtained by accessing only four pixels values rather hundred at a time. In order to detect a single object HAAR object detector takes advantage of three different types of rectangular features which are:

- Edges feature
- Line Feature
- Combinations of four-rectangles feature

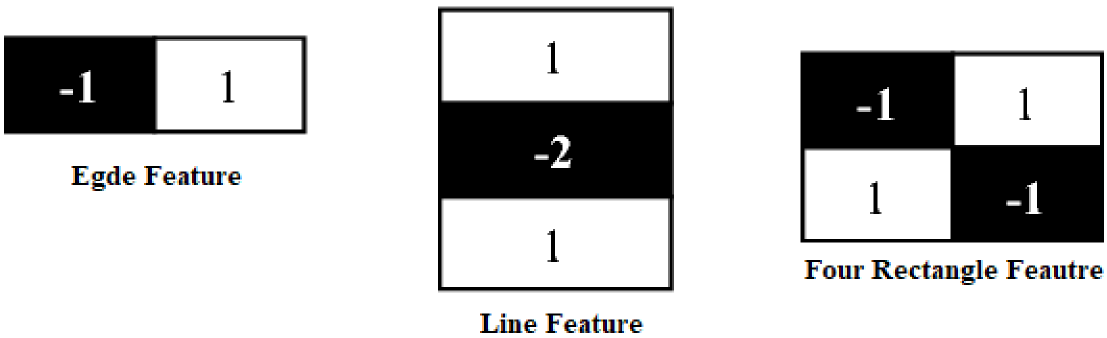

Figure 3.6: HAAR features

HAAR algorithm combines thousands of these rectangles in different regions and combines these features to define an object and detect it efficiently. Each of these features is recognized very quickly in an integral image since thousands of features are verified thousands of times for every single frame of video. The integral image of the frame allows the software to be much more efficient by effectively calculating the image intensities in advance. For face detection specifically, we can use rectangular features that are present in the face such as cascade containing definitions for the cheeks and nose being brighter than the eye socket, and forehead being one of the brightest portions of the face overall. Thousands of these comparisons are conducted in real time to ensure that a single region of a single frame of video contains a face.

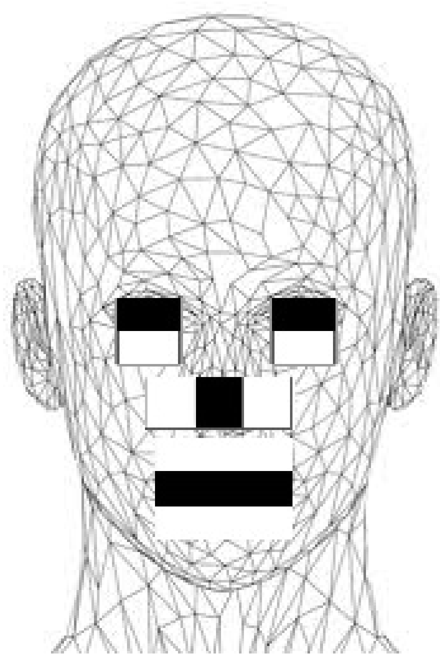

FIGURE 3.7: HAAR features on human face

In short, using HAAR cascade we can efficiently detect the faces present in the image or frame. Moreover, we can also count the number of people present in the frame and also tell the expressions of the people present.

3.4 Face Recognition Algorithm

After detecting the face, the next step is to recognize it. For face detection as well as recognition, we are using face recognition library provided by OpenCV.

The first step is to collect the dataset of the faces that we need to recognize. There is no limit to the number of faces in the dataset. For each person that we need to recognize, we keep a separate folder with a lot of different images of that person. A minimum of 10 different images are required for training for each person. A more efficient dataset is the one, which has images with different backgrounds, different angles and different orientations. The next step is to find a 128-d vector of face embeddings for each person. This vector has floating point values and is generated using a deep neural network. All the data, in the form of a separate 128-d vector for each face, is stored in a pickle file. A pickle file is used in python to serialize objects so it can save data in the form of a file and can be used in a program whenever required.

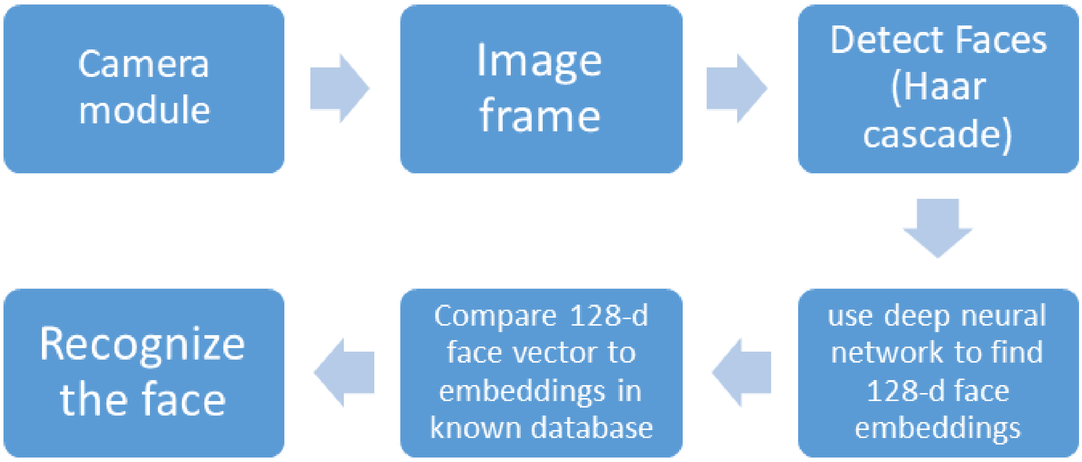

FIGURE 3.8: Face recognition process flow

Now, when we have our pickle file of face embeddings and an xml file of haar cascade, we are ready to perform face recognition. A camera module is used to take live stream of images. Each image or frame is processed separately. First, we take an image and find any faces present in the image using haar cascade. This algorithm returns a bounding box around each face that is detected in the frame. Each face then detected, is used to form a 128-d vector of face embeddings using a deep neural network. For face recognition, this vector is then compared to already computed face embeddings present in the pickle file. If the embeddings match, the face is recognized and the name of the person is returned. If the embeddings donât match any vector in the dataset, we say the person is unknown.

3.5 Water Level Smoke Detection Algorithm

Then we have a Water Sensor that is placed on the cane too and helps the blind to avoid puddles and slippery surfaces. Water sensor consists of simple transistor circuit with two ends of the transistor connected to two probes which are attached to the bottom end of the stick. As soon as the stick will come in contact with water or muddy surface, the two probes will be connected through ions in water and the output of transistor will detect presence of water.

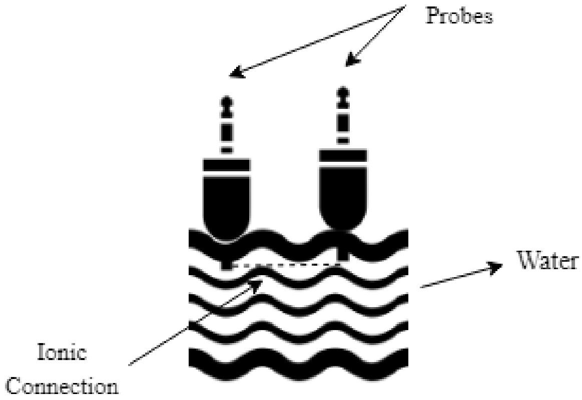

FIGURE 3.9: Water/Puddle detection

Smoke Sensor is our last sensor that is placed on the cane and it gives the user an information about any fire, smoke or combustion gases nearby. Smoke sensor is also able to detect the presence and leakage of different gases.

3.6 Flow Diagram

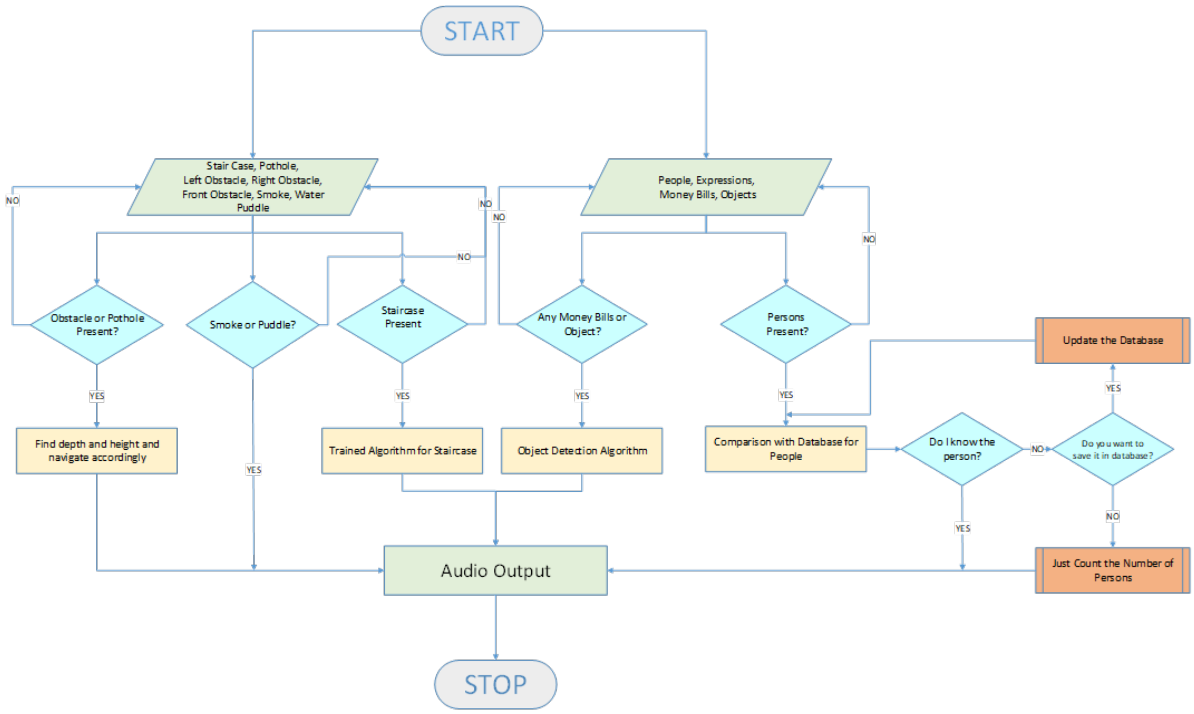

FIGURE 3.10: Flow diagram of methodology

Chapter 4

System Architecture and Design

4.1 Complete System

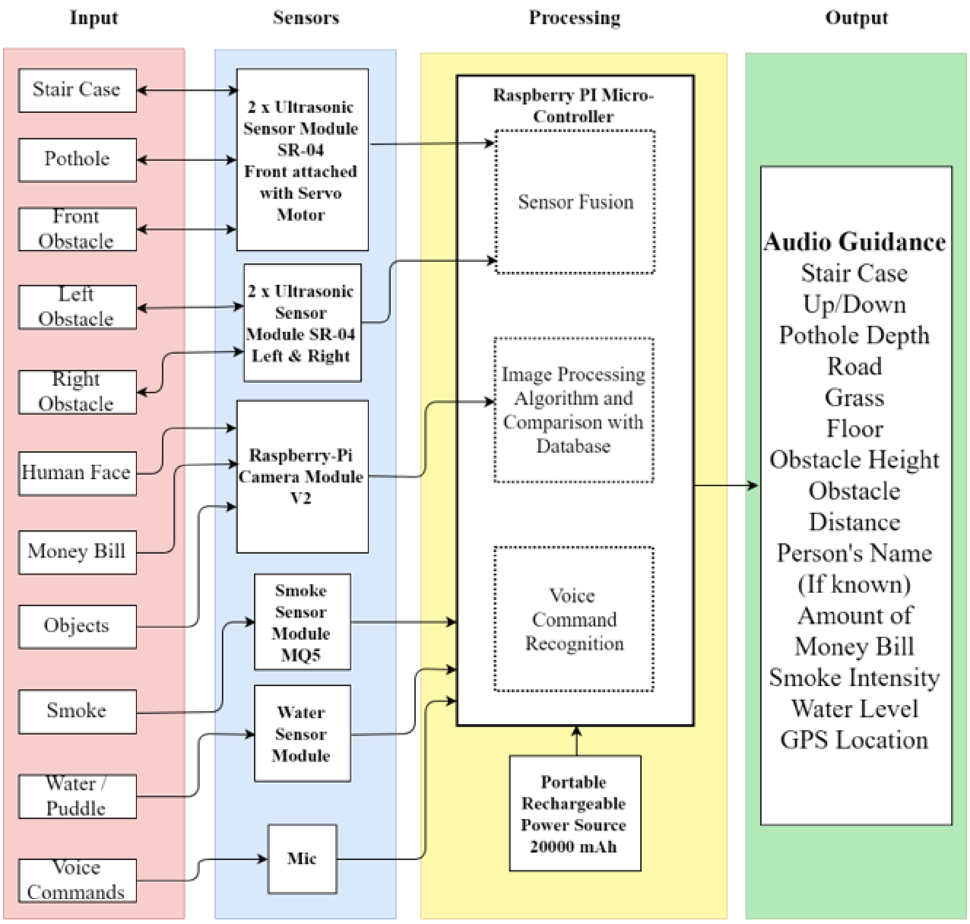

FIGURE 4.1: Block diagram of complete system architecture

4.2 Input Subsystem

This subsystem focuses on taking input from surroundings and processing them to be used by the microcontroller. The input subsystem consists of the following components:

4.2.1 HCSR04 Working

Ultrasonic sensors consists of two major parts i-e receiver and transmitter. The transmitter sends ultrasonic waves into the surrounding after every 25 millisecond. These ultrasonic waves after colliding from an object are received back by the receiver. The process of sending the waves from transmitter is known trigger and the received waves after collision is known as echo. The sensor senses the object as an obstacle if it receives a high signal for at least 10 microsecond.
For proper working, ultrasonic sensors require 5V DC and 15mA current. It can detect obstacles in range 2 cm to 4m.

Five ultrasonic sensors are being mounted on the stick and are used to detect obstacles. Four sensors are static and one sensor is being placed on servo motor.The arrangement is as follows:

FIGURE 4.2: Sensors arrangement on cane

The sensor 1, 2 and 3 are being used to detect front, left and right obstacles respectively. Sensor 4 is used to detect the depth of potholes and downward step. Sensor 5 scans the environment in 180 degrees as it fixed on a servo. It then detects height of obstacles using the required algorithm. Also sensor 5 is used to detect the staircase too along with the help of sensor 1.

4.2.2 Camera Module V2

It is an 8 megapixel camera capable of taking photographs of 3280 x 2464 pixels. It can capture video at 1080p30, 720p60 and 640 x 480p90 resolutions. It attaches to Pi by way of one of the small sockets on the board upper surface and uses the dedicated CSi interface, designed especially for interfacing to cameras. Rpi Camera is being mounted on the smart glasses. Only the lens part is visible from the glasses as shown below: Rpi camera is being to capture live stream of surroundings and thereby identifying the

FIGURE 4.3: Outlook of smart glasses

nearby objects and recognize people. The camera has a 1 meter ribbon cable attached to it. Ribbon cable is used to transmit this data to the microcontroller.

4.2.3 Smoke Sensor MQ-2

The smoke sensor we have used is MQ-2. It detects the presence of methane, butane, LPG and smoke. It requires an operating voltage of 5V. It can be used as an analog or digital sensor. The sensitivity has been adjusted using the potentiometer on the sensor. The sensor is being placed at the bottom of the stick.

4.2.4 Water Sensor Module

Water sensor module is used to detect puddles and other water bodies and alarm the user about it. It is an analog sensor used to detect the absence or presence of water. Water Sensor is an easy-to-use, cost-effective high level/drop recognition sensor, which is obtained by having a series of parallel wires exposed traces measured droplets/water volume in order to determine the water level. Its operating voltage is 5 volts DC. It is placed at the bottom of the smart cane.

4.3 Processing Subsystem

4.3.1 Switch and Microcontroller

The microcontroller used is Raspberry Pi 3B+. It has a 1.4GHz 64-bit quad-core processor, dual-band wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and Power-over-Ethernet support (with separate PoE HAT). Input Power is 5V/2.5A DC via micro USB connector, 5V DC via GPIO header. It has an extended 40-pin GPIO header.

The controller was chosen because of its ability to cater video camera as well as its efficient processing speed. It has a user friendly operating system. The three main benefits of Raspberry Pi include Bluetooth, Wi-Fi and a powerful CPU/GPU pair. The size of the controller is very feasible. Its as small as a credit card and thus making the design of product compact. The built in audio jack also made it one of the most compatible controller for our project.

Microcontroller is placed at the bottom of the stick, inside a case, near the sensors. The sensors are connected to RPi 3B+ using jumper wires as shown below:

A toggle button has also been configured to enable interrupt. Its a two way switch that toggles between different modes as described in the implementation. The switch is placed at the one side of the case.

4.4 Output Subsystem

4.4.1 Earphones and Vibrator Motors

The audio output will be delivered using earphones which are directly connected to the controller. The Raspberry Pi has two audio output modes: HDMI and headphone jack. The other form of output is delivered using vibrating motors. Three vibrator motors are used to deliver all possible combinations for obstacle detection. The motors used require

FIGURE 4.4: Microcontroller inside cane module

3V DC, given from Rpi. The vibrator motors are placed at the position of finger tips. The assembly is shown below:

4.5 Implementation

4.5.1 Data Acquisition

Data collected from different sensors need to be processed before it can be used by the microcontroller to draw further results.

4.5.1.1 Filtering Array

Ultrasonic sensors are taking readings at a very high speed and not all the readings are correct. Sometimes it gives a bogus value momentarily and thereby affect the outcome. To overcome this problem and have an accurate set of readings, a filtering array has been implemented. All the readings are first passed into that array and checked if they all are same. If they are identical, only then these set of readings is passed to the algorithm. In this way, array filters out the irregular and inaccurate readings. After a series of experimentation, the array size is set to be â3â. Hence, it checks for three continuous readings.

4.5.1.2 Video Stream Processing

The stream taken from the camera is at very high resolution and is in RGB format. Therefore, it takes more time in processing and slow down the overall working of the product. Also, the stream coming from the camera is 90 degree rotated because of the physical orientation of lens on the glasses. The data from the camera is being processed in three steps:

1. The frame is first rotated 90 degrees so that it shows the object and face in an upright position.
2. The video is converted to a lower resolution for high processing.
3. The RGB format is being changed to grey format to identify the objects and people.

4.5.1.3 Analog to Digital Conversion

The data collected from smoke sensor and water sensor is in analog form. Rpi microcontroller does not have the facility of ADC converter. Therefore, an integrated circuit has been used here so that the data can be used by the processor. The IC used is MCP3208. This is a python library designed to work with the MCP3208 ADC using SPI on the required microcontroller. The data from sensors is first fed to it.

4.5.2 Interrupt Configuration

All the inputs are coming simultaneously and being processed at the same time. Therefore, two modes have been introduced.

1. Vision mode
2. Navigation mode

User can switch between these modes using a push-pull button. This switch has been implemented using interrupts in python. The state of switch decides the mode.

4.5.3 Output

4.5.3.1 Audio Output

The output is given in the form of audio since the person is blind. For audio output we have used âosâ library in python. It generates a .wav file which is then played. The output is being played as soon as the obstacle, face or object is detected. To avoid the continuously annoying audio, flags have been implemented so that the user listen the output only once and does not hear it repeatedly for the same object.

4.5.3.2 Haptic Feedback

Haptic feedback means the use of âtouchingâ sense to communicate with the users. The haptic feedback is given via motors. The motors are connected to the controller and are associated with the obstacle detection algorithm. A specific combination of motors vibrate for each type of obstacle. Each motor is connected on a GPIO pin.

4.6 Product Design Process

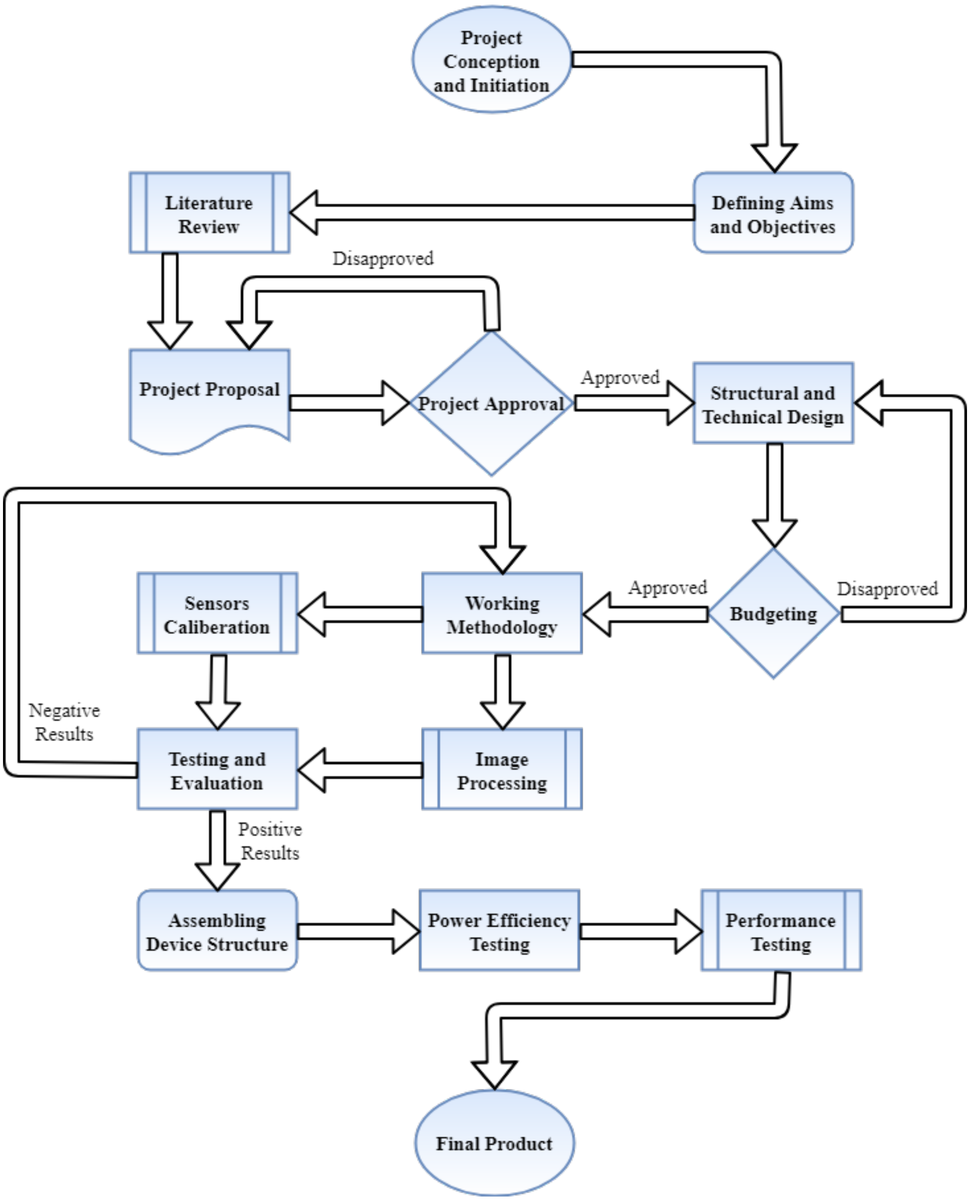

FIGURE 4.5: Product Design Process

4.6.1 Design of Smart Cane

The design of smart cane is as follows:

FIGURE 4.6: Design of smart cane

The design has the following characteristics:

- The weight of cane is 500 grams
- The placement of Rpi near the sensors reduces the number of jumpers used and the noise due to them.
- The Rpi is being placed inside a case so that it is protected twice i-e in its Rpi casing and the modeling sheet casing.
- The external power supply to power up sensors and and Rpi is also being placed inside casing.
- Since the major weight is being placed near the ground, the cane has a low centre of gravity.

4.6.2 Design of Smart Glasses

The design of smart glasses is as follows:

FIGURE 4.7: Design of smart glasses

The design has the following characteristics:

- The glasses has a hole for Rpi camera on the right lens.
- The cameraâs PCB is being covered with tape and soft material so it doesnât irritate the user.
- The flex cable is 2m long making it easier to reach the glasses from the controller.

Chapter 5

Results And Discussion

In this chapter the results will be obtained by testing the designed the product for different features. All the features will be tested to measure their accuracy, range and response time. Accuracy is the most important metric to evaluate for any product developed to help a disabled person. As this product is developed for the blind, its accuracy should be measured and informed to the user. In this way the user will have an idea about the feasibility of this product and will have an idea how much the output of this product should be trusted. Range of any feature describes the extent of its scope. Response time is very important to measure when it comes to aiding devices. The value of response time of all readings and outputs must be low enough to inform the user about the obstacles, danger and objects around him/her.

5.1 For Smart Cane

Smart cane provides obstacle detection, staircase detection, depth measurement, height measurement, water/puddle detection and smoke detection. Results of tests for all of these features will be discussed in following sections.

5.1.1 Obstacle Detection

Obstacle detection feature is one of the most basic necessity of blind people. Due to this reason this feature should be fast, accurate and robust.

5.1.1.1 Response Time

The response time for obstacle detection depends on the time of round trip of ultrasonic wave after reflecting from obstacle. As the speed of ultrasonic waves is 344 m/s and considering the range of HCSR04, following calculations can be made.

$$Speed\ of\ ultrasonic\ wave =\ 344m/s \tag{5.1}$$

$$Max\ distance\ range\ of\ HCSR04\ = 4m \tag{5.2}$$

$$Round\ trip\ distance\ = 4 * 2 = 8m \tag{5.3}$$

Using,

$$Time\ =\ Distance/Speed \tag{5.4}$$

$$Response\ time\ =\ 8/344 = .33ms \tag{5.5}$$

5.1.1.2 Range

The ultrasonic sensor HC-SR04 offers excellent range for obstacle detection with accuracy as calculated above. From minimum range of 2 cm to maximum range of 400 cm. Its working is not affected by sunlight or black objects but acoustically soft objects like cloth can be refract waves rather than reflecting them, which makes them difficult to detect.

$$Minimum\ obstacle\ range\ =\ 2cm \tag{5.6}$$

$$Maximum\ obstacle\ range\ =\ 400cm \tag{5.7}$$

5.1.1.3 Accuracy

Accuracy of obstacle detector is tested using confusion matrix. Confusion matrix shows what was the actual obstacle and what device predicted. The product is tested for 200 different kinds front, left and right obstacles. Accuracy is obtained by dividing the correctly identified obstacles by total number of obstacles.
As explained in the methodology a filter of moving array is used to improve accuracy, it can be seen in following tables that the without moving array filter accuracy of obstacle detector is 95% (table 5.2) while accuracy of obstacle detector with moving array filter of array size 3 is 100% as shown in table 5.1.

$$Accuracy\ without\ filter\ = \frac{Correctly\ Detected\ Obstacles}{Total\ Obstacles} \tag{5.8}$$

$$= \frac{190}{200} * 100 = 95\% \tag{5.9}$$

$$Accuracy\ with\ filter\ = \frac{Correctly\ Detected\ Obstacles}{Total\ Obstacles} \tag{5.10}$$

$$= \frac{200}{200} * 100 = 100\% \tag{5.11}$$

		Predicted			
		Front	Right	Left	None
Actual	Front	50	0	0	0
	Right	0	50	0	0
	Left	0	0	50	0
	None	0	0	70	50

TABLE 5.1: Confusion matrix for array filter of size 3 of Obstacle detection

		Predicted			
		Front	Right	Left	None
Actual	Front	48	0	0	2
	Right	0	50	0	0
	Left	0	1	47	2
	None	2	2	1	45

TABLE 5.2: Confusion matrix without array filter of Obstacle detection

5.1.2 Depth Measurement

Depth measurement plays an important part to prevent the user from stepping into a pothole or falling over deep steps.

5.1.2.1 Response Time

As depth detector is also based on same ultrasonic sensor HC-SR04 as obstacle detector it would have same response time which is:

$$Response\ time\ = 2.33ms \tag{5.12}$$

5.1.2.2 Range

The minimum depth which can be detected by the cane cannot be set smaller than the length of normal step. The reason is that when the user is walking he slightly lifts the stick for about 5 cm high. If the the minimum depth range is set less than 10 cm, then according to the above explained methodology, the stick would give false positive readings for a pothole. So, the minimum range for depth which will alarm the user through vibrators or audio is set to 10 cm. Maximum range is same as the maximum range of ultrasonic sensor used.

$$Minimum\ depth\ = 10cm \tag{5.13}$$

$$Maximum\ depth\ = 400cm \tag{5.14}$$

5.1.2.3 Accuracy

Accuracy of depth measurement feature is measured by measuring the error between the measured depth and the actual depth. After comparing values 10 values table 5.3 was obtained.

Actual Depth cm	Measured Depth cm	Difference Error	Squared Error
	20	20.7	-0.7
0.49			
	25	26	1
1			
	30	31	-1
1			
	35	36.5	-1.5
2.25			
	40	41	-1
1			
	45	46.2	1.2
1.44			
	50	52	-2
4			
	55	57.3	-2.3
5.29			
	60	63	-3
9			

TABLE 5.3: Iterated Experiments for Depth Measurement

$$Mean\ square\ error = \frac{Summation(SquaredError)}{TotalNumberOfReadings} = \frac{25.72}{10} = 2.572 \tag{5.15}$$

$$Root\ mean\ square\ error = 1.604 \tag{5.16}$$

$$Accuracy = 100 - Mean\ square\ error\ = 98.4\% \tag{5.17}$$

5.1.3 Staircase Detection

Staircase detection for both upstairs and downstairs should be accurate and robust as upstairs are similar to front obstacles and downstairs are similar to potholes.

		Predicted	
		Upstairs	Front Obstacle
Actual	Upstairs	47	3
	Front Obstacle	0	50

TABLE 5.4: Confusion matrix For Upstairs case detection

5.1.3.1 Response Time

As again staircase detector uses ultrasonic sensors, so the response time will be same as obstacle detector.

$$Response\ time\ for\ upstairs\ = 2.33ms \tag{5.18}$$

5.1.3.2 Range

Range for stairs is the minimum and maximum distance from which stairs can be detected.

$$Minimum\ distance\ for\ upstairs\ detection\ = 2cm \tag{5.19}$$

$$Maximum\ distance\ for\ upstairs\ detection\ = 100cm \tag{5.20}$$

For downstairs, the user will have to keep the cane little forward as the stick should just behind downstairs.

5.1.3.3 Accuracy

For accuracy measurement same confusion matrix technique is used. As upstairs case is confusing with front obstacles, the device was tested for for 50 different kinds upstairs and 50 different kinds front obstacles and following confusion matrix is obtained, shown in table 5.4.

$$Accuracy\ Upstairs\ Detection\ = \frac{97}{100} = 97\%$$

(5.21)

For downstairs, they get confused with potholes for the device. The device detects downstairs step by using average staircase rise which 19.7 cm. Considering the mean square error of 1.6 %, the range for a downstairs step is set to 17 cm to 23 cm. Again confusion matrix technique was used to measure accuracy of downstairs detection.

$$Accuracy\ down\ staircase\ detection\ = \frac{87}{100} = 87\% \tag{5.22}$$

		Predicted	
		Down stairs	Pothole Obstacle
Actual	Down stairs	44	6
	Pothole Obstacle	7	43

Table 5.5: Confusion matrix For Down Staircase detection

5.1.4 Water/Puddle Detection

Water level sensor module used to detect water or puddles on pathways of the blind user is very accurate and has very small response time. It is an analog sensor.

5.1.4.1 Response Time

As it is an analog sensor, the reading are obtained as fast as the stick touches wet place.

$$Response\ time = 0s \tag{5.23}$$

5.1.4.2 Range

The water sensor can detect water, puddle or wet surface up to 4 cm deep. The device is configured to alarm the user when the stick touches water level or puddle up to 1 cm. So, the blind user will have to carefully listen to the output as he/she pushes the stick in water or puddle. As he/she keeps pushing the stick in water, the device will alarm after every 1 cm. The user should stop at 4 cm. The device is configured to alarm the user when the stick touches water level or puddle up to 1 cm. If the user pushes the stick in water deeper than that, it can short circuit the water sensor.

$$Minimum\ water/puddle\ level\ = 1cm \tag{5.24}$$

$$Maximum\ water/puddle\ level\ = 4cm \tag{5.25}$$

5.1.4.3 Accuracy

Accuracy of the sensor module is perfect. All the moist and wet surfaces are detected with accuracy.

$$Accuracy\ of\ water\ sensor\ = 100\% \tag{5.26}$$

5.1.5 Smoke Detector

Smoke detector plays a very vital role in this device, in emergency cases like fire, smoke and suffocation. Smoke sensor module MQ2 is used for gas leakage detection.Due to its high sensitivity and fast response time, measurement can be taken as soon as possible. The sensitivity of the sensor can be adjusted by potentiometer.

5.1.5.1 Response Time

Similar to water sensor, this sensor is also analog. As soon as there is smoke in the users environment, the alarm will go off.

$$Response\ Time\ for\ smoke\ sensor\ = 0seconds \tag{5.27}$$

5.1.5.2 Range

It is can detect gases like. H2, LPG, CH4, CO, Alcohol, Smoke or Propane.

5.1.5.3 Accuracy

This sensor is very accurate,and detects smoke successfully.

$$Accuracy\ for\ smoke\ detector\ = 100\% \tag{5.28}$$

5.2 For Smart Glasses

Smart glasses are the comfort and luxury which this device provides to blind people. It has features of face detection, face recognition, smile detection and object identification. Their results are discussed as follows.

5.2.1 Face Detection

Face detection feature is used to identify number of faces in front of the blind user.

5.2.1.1 Response Time

The response time of this feature depends on the frame rate. Frame rates are calculated in terms of frames per second (fps).

$$Frame\ rate\ of\ face\ detection\ =\ 2.5fps \tag{5.29}$$

$$Response\ Time\ of\ Face\ Detection\ = 0.4s \tag{5.30}$$

5.2.1.2 Range

The person whose face is being detected should be standing face to face towards the blind person. The range of distance of the guy whose face is being detected as follows:

$$Minimum\ distance\ of\ face\ from\ camera = 20cm \tag{5.31}$$

$$Maximum\ distance\ of\ face\ from\ camera = 100cm \tag{5.32}$$

		Predicted	
		Face	No Face
Actual	Face	50	0
	No Face	0	50

TABLE 5.6: Confusion matrix For Face detection

		Predicted	
		Face	No Smile
Actual	Face	42	8
	No Smile	3	47

TABLE 5.7: Confusion matrix For Smile detection

5.2.1.3 Accuracy

Accuracy for face detection algorithm is very high for above mentioned range. Same confusion matrix technique to measure accuracy of face detector.

$$Accuracy\ face\ Detection\ = \frac{100}{100} = 100\% \tag{5.33}$$

5.2.2 Smile Detection

Smile detection is similar to face detection. It detects smile in a frame after it detects the face.

5.2.2.1 Response Time

Smile detection has same response time as face detection as both work on OpenCV and has same fps.

$$Frame\ rate\ of\ smile\ detection = 4fps \tag{5.34}$$

$$Response\ Time\ of\ smile\ detection\ = 0.25s \tag{5.35}$$

5.2.2.2 Range

Smile detection has same range as of face detector, due to same camera and frame size is being used.

$$Minimum\ distance\ of\ face\ from\ camera = 20cm \tag{5.36}$$

$$Maximum\ distance\ of\ face\ from\ camera\ = 100cm \tag{5.37}$$

5.2.2.3 Accuracy

The accuracy of smile detector is also measured by using confusion matrix.

$$Accuracy\ face\ Detection\ = \frac{89}{100} = 89\% \tag{5.38}$$

5.2.3 Face Recognition

Face recognition is one of the most vital and significant feature of smart glasses, as recognizing your family and friends is the desire and need of every blind person. The accuracy of this feature is important and must improved as much as possible. False positives can result in making the user vulnerable.

5.2.3.1 Response Time

Response time for face recognition is slightly higher than face detection as in case of face recognition, the generated 128-D Vector is compared with D Vectors of faces in database. It takes time for processor to perform vector matching which result in lower fps and higher response time.

$$Frame\ rate\ of\ face\ detection\ = 2.5fps \tag{5.39}$$

$$Response\ time\ of\ smile\ detection\ = 0.4s \tag{5.40}$$

5.2.3.2 Range

Range for face recognition is same as face detection, as face recognition algorithm also uses OpenCV.

$$Minimum\ distance\ of\ face\ from\ camera\ = 20cm \tag{5.41}$$

$$Maximum\ distance\ of\ face\ from\ camera\ = 100cm \tag{5.42}$$

5.2.3.3 Accuracy

To test the face recognition model, 30 pictures of all four group members of this project were provided to train the classifier for their faces. After training the algorithm accuracy was tested using testing data which consisted of 20 pictures of each member, 10 pictures of unknown males and 10 pictures of unknown females. The obtained confusion matrix is as follows:

$$Accuracy\ of\ face\ Detector\ = \frac{87}{100} = 87\% \tag{5.43}$$

		Predicted				
		Murtaza	Hadia	A.Khurram	A.Rehman	Unknown
Actual	Murtaza	20	0	0	0	0
	Hadia	0	18	0	2	0
	A.Khurram	0	0	19	0	1
	A.Rehman	0	2	0	16	2
	Unknown	3	1	2	0	14

Table 5.8: Confusion matrix For Facial Recognition

5.2.4 Object Detector

Object detector uses a Coco model dataset of 90 objects for detection daily life common objects. These objects are detected with accuracy due the vast dataset and robust training.

5.2.4.1 Response Time

Response time is limitation of object detector as it uses tensorflow model, which is quite heavy for Raspberry Pi processor. The frame rates are very low as compared to OpenCV.

$$Frame\ rate\ of\ object\ detection = 0.8fps \tag{5.44}$$

$$Response\ time\ of\ smile\ detection\ = 1.25s \tag{5.45}$$

5.2.4.2 Range

The range of objects in terms of distance which can be detected is:

$$Minimum\ distance\ of\ object\ from\ camera\ = 15cm \tag{5.46}$$

$$Maximum\ distance\ of\ object\ from\ camera\ = 150cm \tag{5.47}$$

5.2.4.3 Accuracy

As mentioned above, that this object detection model has high response time but on the other hand it provides very high accuracy due to large dataset. 5 common life objects were used to develop confusion matrix. Different kinds of bottles, phones, scissors, cups and bags were used for testing data.

$$Accuracy\ of\ face\ detector\ = \frac{100}{100} = 100\% \tag{5.48}$$

		Predicted				
		Bottle	Phone	Scissor	Cup	Bag
Actual	Bottle	20	0	0	0	0
	Phone	0	20	0	0	0
	Scissor	0	0	20	0	
	Cup	0	0	0	20	0
	Bag	0	0	0	0	20

Table 5.9: Confusion matrix For Object Detection

Chapter 6

Conclusion

Conclusively, smart cane and glasses is a complete product for the blind community allowing them to move in the society independently. It is an attempt to provide them maximum features in a low budget keeping in view the performance, quality and specifications. A whole lot of features can be introduced in the future. The future aspects of this product include money bill detection, better design and modular approach towards the components. The product can be commercialized and can be used to create a start-up idea. The project has been represented at various platforms. Some of the achievements include:

1- Top Business idea at Battle of Minds

2- Exhibited in MakerFest Pakistan

3- Participated in Stem Competition

4- Featured at SAMAA News Channel

5- Interviewed by Waqt News

The product was appreciated at all platforms by the audience and judges. It was most appreciated by our test subject, Mr.Ali Hassan. He described this product in the following words,

"This stick made me feel secured as I could detect hurdles at a distance and from all sides.I can now recognize people and objects. Its like a miracle"

References

[1] "Universal eye health: a global action plan 2014–2019," *World Health Organization*, 2013.

[2] S. Achieng, "Africa and asia lead in proportion of blind adults," *Sci Dev Net*, 2017.

[3] M. Z. Jadoon, B. Dineen *et al.*, "Prevalence of blindness and visual impairment in pakistan: The pakistan national blindness and visual impairment survey," *Invest Ophthalmol Vis Sci. (IOVS)*, vol. 11, November 2006.

[4] P. R. R. A. Bourne *et al.*, "Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis," *The Lancet Global Health*, vol. 5, pp. 888–897, September 2017.

[5] (2019) Jpma - journal of pakistan medical association. [Online]. Available: http://www.jpma.org.pk

[6] (2019) Pakistan bureau of statistics. [Online]. Available: http://www.pbs.gov.pk

[7] (2019) Wewalk: Revolutionary smart cane for the visually impaired. [Online]. Available: https://www.wewalk.io

[8] (2019) Bawa cane â recreating hope. [Online]. Available: https://www.bawa.tech

[9] (2019) Ultracane....putting the world at your fingertips. [Online]. Available: https://www.ultracane.com

[10] V. Singh, R. Paul, D. Mehra, A. Gupta, V. Sharma, S. Jain, C. Agarwal, A. Garg, S. Singh Gujral, M. Balakrishnan, K. Paul, and P. Rao, "'smartâ cane for the visually impaired: Design and controlled field testing of an affordable obstacle detection system," 04 2019.

[11] I. Y. Chung, S. Kim, and K. H. Rhee, "The smart cane utilizing a smart phone for the visually impaired person," in *2014 IEEE 3rd Global Conference on Consumer Electronics (GCCE)*, Oct 2014, pp. 106–107.

[12] A. A. Nada, M. A. Fakhr, and A. F. Seddik, "Assistive infrared sensor based smart stick for blind people," in *2015 Science and Information Conference (SAI)*, July 2015, pp. 1149–1154.

[13] S. Murali, R. Shrivatsan, V. Sreenivas, S. Vijjappu, S. J. Gladwin, and R. Rajavel, "Smart walking cane for the visually challenged," in *2016 IEEE Region 10 Humanitarian Technology Conference (R10-HTC)*, Dec 2016, pp. 1–4.

[14] S. Sharma, M. Gupta, A. Kumar, M. Tripathi, and M. S. Gaur, "Multiple distance sensors based smart stick for visually impaired people," in *2017 IEEE 7th Annual Computing and Communication Workshop and Conference (CCWC)*, Jan 2017, pp. 1–5.

[15] L. Tian, Y. Tian, and C. Yi, "Detecting good quality frames in videos captured by a wearable camera for blind navigation," in *2013 IEEE International Conference on Bioinformatics and Biomedicine*, Dec 2013, pp. 334–337.

[16] Y. Jin, J. Kim, B. Kim, R. Mallipeddi, and M. Lee, "Smart cane: Face recognition system for blind," 10 2015.

[17] C. Alvarez Casado, M. Bordallo Lopez, J. Holappa, and M. PietikÃinen, "Face detection and recognition for smart glasses," 06 2015.

[18] N. Sumi and V. Moshnyaga, "A novel face recognition for smart glasses," in *2016 IEEE Region 10 Symposium (TENSYMP)*, May 2016, pp. 115–118.

[19] R. Agarwal, N. Ladha, M. Agarwal, K. K. Majee, A. Das, S. Kumar, S. K. Rai, A. K. Singh, S. Nayak, S. Dey, R. Dey, and H. N. Saha, "Low cost ultrasonic smart glasses for blind," in *2017 8th IEEE Annual Information Technology, Electronics and Mobile Communication Conference (IEMCON)*, Oct 2017, pp. 210–213.