Outdoor Obstacle Detection Module to Assist Visually Challenged

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Abstract Autonomous navigation is of utmost importance for people suffering from visual impairment problems in their daily life. At present, a device known as Electronic Travelling Aids (ETA) is used by the visually impaired to detect static objects. As it is to be held by hand, it limits them from performing some of their activities. The objective of this project is to provide a hands-free module which focusses on dynamic objects (car) in an outdoor environment. This is achieved by using Raspberry Pi module, camera and ultrasonic sensor. The vehicle is captured by the camera in real time and detected using image processing techniques and Haar Cascade classifier. The ultrasonic module scans for the obstacle in three different directions, and then intimates the user to move away from the obstacle using an audio output, which is provided through headphones. The above-mentioned modules are incorporated into a waist belt. This prototype would be a better choice than the existing modules as it is long-lasting, hands-free, detects dynamic objects and helps the user in dauntless navigation in the outdoor environment.

Keywords Visual impairment · Raspberry pi · Haar cascade classifier · Ultrasonic sensor · Dynamic obstacle · Hands-free waist belt

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1 Introduction

Vision impairment refers to when you lose a part or all of your ability to see (vision). This cannot be fixed by usual means such as glasses or contact lenses. 2011 WHO statistics show that there are 285 billion people in the world with visual impairment, 39 billion of people are blind, 246 billion are with low vision and 15 million people are blind in India [1]. However, it is estimated that the number of people with vision impairment could triple due to population growth and ageing. For example, by 2050, there could be 115 million people who are blind, up from 38.5 million in 2020. The statistics reveal that the causes of visual impairment are due to cataract (47.9%), glaucoma (12.3%) and age-related macular degeneration (AMD) (8.7%). Mobility is one of the major problems encountered by the visually impaired people in their daily life. By the roll of vision, people are able to move from one place to another. Without the vision, people will feel insecure while walking even in familiar places such as home, workplace. So, they need assistance for their mobility. It is impossible for a person to be always there to assist them. A common assistive device used by the visually impaired are the white cane. It is a mechanical cane which will provide tactile feedback when they sense an obstacle in front of them [2]. Ultrasonic sensors are widely used for the detection of obstacles in front [3–7]. Currently, a device known as Electronic Travelling Aids (ETA) is used to help the blind in managing a daily routine [8, 9]. The main drawbacks of ETA are that they are not long-lasting, they are uncomfortable to hold for long periods of time and they can detect only static, nonspecific objects [10]. Most of the assistive devices that are available in the market fail to provide for a hands-free environment for the blind. Hands-free environment will be convenient for the visually impaired and gives them a more sophisticated and aesthetic environment. Most of the devices are designed in a way that they are to be held in the hand and used indoors [11]. This will make the visually impaired to limit some of their activities as the normal persons do. This project aims to provide an economical, hands-free travelling guide to help the visually impaired get informed about an approaching dynamic object (car) in an outdoor environment [12]. It provides an improved navigation to the user by communicating to the user through voice alert or a buzzer output, thus enabling an easy and comfortable navigation to the user [13].

2 Methodology

Dynamic objects (cars) in the outdoor environment are detected by Raspberry Pi 3, Pi camera and ultrasonic module using image processing techniques. The classifier module used in the detection process is obtained using Haar training. Depending on the distance of the object calculated by the ultrasonic sensors, the user is intimated to move away from the approaching object via buzzer or audio output. These assistive

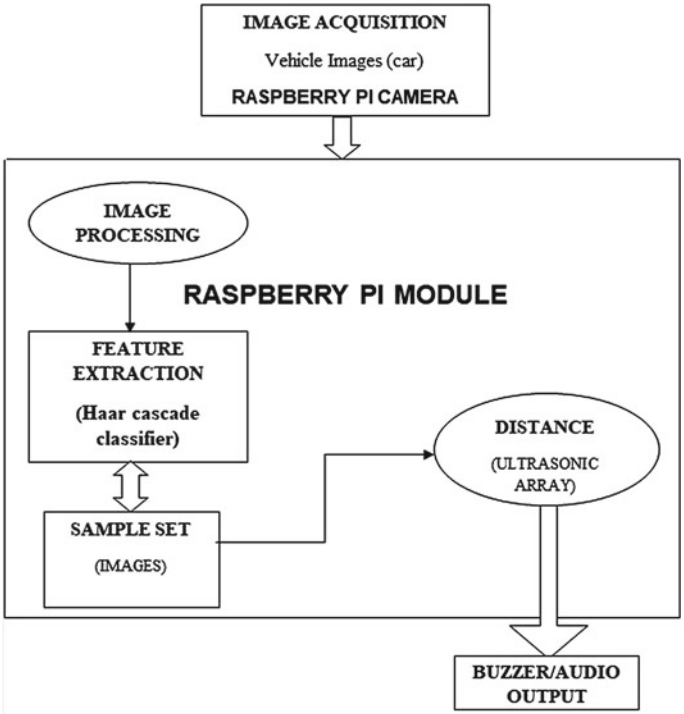

Fig. 1 Flow diagram

modules are incorporated into a waist belt, thus making it a hands-free module. Figure 1 depicts the flow of designing the outdoor obstacle detection module.

2.1 Block Diagram

The Raspberry Pi camera is used to capture the nearing car in real time. The resolution of the captured frames is changed using image processing techniques and it is then detected using Haar Cascade classifiers. On detection, the ultrasonic module is triggered and the distance between the vehicle and the user is calculated. When a specified threshold is reached, the user is provided with an audio output that specifies the direction in which the user has to move in order to avoid the vehicle.

2.2 Image Acquisition

The images used for training are acquired manually by taking pictures of multiple cars in different locations at various angles using a 5 Mp Omni vision Raspberry Pi camera module. The sample set, containing 2033 positive (car) and 1041 negative (non-vehicle) images is fed into the classifier for the training process. The resolution of the captured image is 2592 × 1944.

2.3 Image Processing

The image has to be processed before detection. On powering up the Raspberry pi, the video of the approaching car is captured in real time using Raspberry Pi camera at 1080 pixels and 30 frames per rate. The captured video is converted into image frames. Then, the grey scale conversion and alteration of resolution is performed to facilitate the detection process.

2.4 Haar Training

Haar feature-based cascade classifiers are a machine learning approach which is extremely rapid in detecting the objects in an image and video [14]. Every region of the image is analysed using a set of classifiers called Haar features that act as a funnel called Haar Cascade [15]. Figure 2 explains the generation of classifier module using the features extracted from an obtained sample data set containing large number of positive and negative images. The preliminary training and the acquiring of the trained file (XML module) are done in the Windows platform and using the Visual Studio 2017 software. It is later incorporated into the Raspberry Pi module using its terminal. The OpenCV computer program and its related modules are used for the real-time computer application.

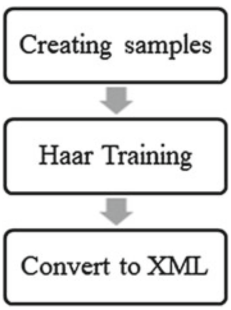

Fig. 2 Steps involved in Haar training

2.5 Distance Measurement

The HC-SR04 ultrasound module is used to measure the distance of the detected car from the user. A pulse of 10 μs is used to trigger it. The transmitter emits a high-frequency ultrasonic sound, which bounces off any nearby solid objects. Some of that ultrasonic noise is reflected and detected by the receiver on the sensor. That return signal is then processed by the control circuit to calculate the time difference between the signal being transmitted and received. This time it can subsequently be used, along with some clever math, to calculate the distance between the sensor and the reflecting object. Depending on the distance measured, the output is intimated to the user, either through buzzer or headphones.

3 Device Set up

The prototype to detect dynamic objects (car) in an outdoor environment employs the Raspberry Pi 3, Raspberry Pi camera, Ultrasonic sensors, buzzer module and any type of headphones.

3.1 Raspberry Pi Module

The Raspberry Pi 3 Model B is used which is a single-board computer with wireless LAN and Bluetooth connectivity. It is basically a mini computer which works just as fast as a home PC depending on the model. It has a Quad Core 1.2 GHz Broadcom BCM2837 SoC (system on a chip) which includes an ARM Cortex A-53 64-bit CPU and a 40-pin extended GPIO. A 1 GB RAM memory range is available on board. It consists of four ports, namely Full-size HDMI, CSI Camera port for connecting Raspberry Pi camera, DSI Display port for connecting a display, a MicroSD port for loading the OS and storing the data. In Raspberry Pi Model B, the Ethernet port is provided by a built-in USB Ethernet.

3.2 Raspberry Pi Camera

The Raspberry Pi Camera Board plugs directly into the CSI connector on the Raspberry Pi. It is able to deliver a crystal clear 5 MP resolution image, or 1080p HD video recording at 30 fps. The camera board attaches to the Raspberry Pi via a 15-way ribbon cable. There are only two connections to make: the ribbon cable needs to be attached to the camera PCB and the Raspberry Pi itself.

3.3 Hc-Sr04 Ultrasonic Module

The HC-SR04 ultrasound module is used for the purpose of calculating the distance between the user and the detected car. Pulse duration is the full time between the sensor outputting an ultrasonic pulse, and the return pulse is being detected by the sensor receiver [16]. The Python script measures the pulse duration, and then calculate the distance (Eq. 1) from this. This pulse duration is multiplied with speed of ultrasonic and then divided by two. Mathematically,

$$\text{Distance (m)} = \frac{\text{Time duration (s)} \times 34300\ (\text{m/s})}{2} \quad (1)$$

where
Speed of ultrasound in air = 34300 m/s

3.4 Buzzer/Audio

SB-01 buzzer is initially connected to Raspberry Pi. Based on the obstacle detected by single ultrasonic, the buzzer module is activated. This emits a shrill sound on detection. In case of a single ultrasonic sensor, a buzzer output is produced. Once the car has been detected, the ultrasonic module determines its distance from the user. The buzzer then emits a loud beep thus alerting the user.

4 Results and Discussions

Conventionally, people suffering from visual impairment problems used walking sticks to navigate. At present, Electronic Travel Aids (ETA) is used to detect static objects. The aim of the project is to provide a hands-free module to detect dynamic objects (car) in an outdoor environment. This is done using Raspberry Pi, camera and Ultrasonic sensors.

4.1 Real-Time Output

The working of the prototype is tested in the outdoor environment using the Raspberry Pi and its camera module. This uses real-time streaming video, which means that the video capturing and the detection process are carried out simultaneously.

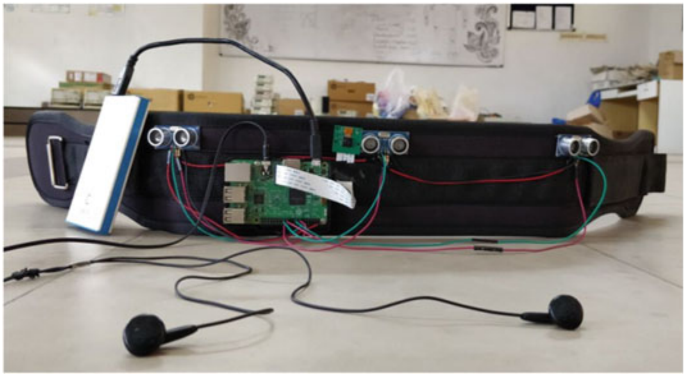

Fig. 3 Final prototype

4.2 Ultrasonic Output

Using the ultrasonic module, the distance of the detected obstacle is found. Once the car is detected, the ultrasonic module is triggered. The module detects the car up to a range of 5 m. Three ultrasonic sensors at three different angles (±180° and +90°) in the form of an array are used. For single ultrasound, once the car is detected, the ultrasonic module determines its distance from the user. The buzzer then emits a loud beep thus alerting the user. In this case, the user is not given any useful commands to avoid the obstacle which is the drawback with this setup. So, the ultrasonic array setup is used. In the case of an ultrasonic array, an audio output given via headphones is used. This tells the user to move in a particular direction in order to avoid the car (Fig. 3).

4.3 Buzzer/Audio Output

The buzzer emits loud beeps as a moving car passes, provided it is within the ultrasonic range. This output is further improved using an audio output (Table 1) via headphones.

Table 1 Audio output

Object position	Sensor reading (m)	Reading output
Left	0–5	Move right
Straight	0–5	Move right or left
Right	0–5	Move left

4.4 On-Field Detection

All the supporting modules (Raspberry Pi module, Raspberry Pi camera and Ultrasonic sensors) explained in the methodology is incorporated into a waist belt (Fig. 3). The ultrasonic sensors are fitted onto the belt and focussed in such a way that all the three major directions (±180° and +90°) are covered.

During the on-field detection, the user is made to stand in an outdoor environment (road) with the belt worn around his/her waist. It is observed that for every car that approached the user, detection occurred and the audio output is heard. It states the proper direction that the user has to move in order to avoid the vehicle. It is also observed that the detection of other obstacles like static objects, people in motion and bicycles are ignored. The detection speed for multiple cars is found to be quick and there is minimum or no time lag.

5 Conclusion

The detection of cars in an outdoor environment is performed using Raspberry Pi module, camera and Ultrasonic array. The classifier module is generated by the features extracted from a manually obtained sample data set including positive (car) and negative (non-vehicle) images. It is initially tested on virtual platform followed by real-time detection along with reduced misclassifications. Single ultrasonic sensor and buzzer are interfaced with Raspberry Pi to detect and calculate the distance of the detected car in front of the user. An ultrasonic array of three ultrasonic sensors and headphones are interfaced to the Raspberry Pi to detect and calculate the distance of the car in three directions surrounding the user. An audio output intimates the user whether to move right (or) move left (or) move left or right based on the direction of the approaching car.

Further work is to add on to the level of accuracy in detection by using ultrasonic sensors with higher range and to integrate three Raspberry Pi cameras or pan and tilt setup to improve direction specificity. The algorithm may be extended to differentiate various dynamic obstacles in the outdoor environment so as to provide a more precise output.

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