On time audio alert automated intelligent system for visually impaired people

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Article Info

Article history:

Received May 6, 2024
Revised Jan 20, 2025
Accepted Mar 29, 2025

Keywords:

Audio alert
Blind glass
Object detection
Raspberry Pi
Ultrasonic sensor

ABSTRACT

India is the home of the world's blind population. The country has around 12 million individuals with visual impairment against a global total of 39 million according to a report published by the National Programme for Control of Blindness. Visually impaired people cannot live independently. They have to depend on others for their daily activities. The major problem occurs when blind people walk on the road, they cannot detect any obstacle which puts them at risk. sometimes it causes major injuries and accidents. With the proposed system, visually impaired people can walk on the road independently. A device with internet of things (IoT) technology where smart glass is embedded with an ultrasonic sensor, sunglasses, Raspberry Pi, voice module ISD1820, and Bluetooth. This device alerts the user with audio guidance. When people walk in front of an obstacle, the device detects the obstacle and tells the user at what distance the obstacle is there. They can walk on the road comfortably and fearlessly. It gives audio alerts about obstacles to the user. The key features are it is easy to wear, lightweight, and cost-effective. Wearing smart glasses, they can walk on the road confidently like a normal human being without any guilt.

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1. INTRODUCTION

In our contemporary, technology-centric society, ensuring accessibility for every individual is not only a moral obligation but also an essential requirement. Visually impaired individuals face distinct obstacles when it comes to navigating the world, such as difficulties in reading printed language, identifying things, and moving around unfamiliar surroundings. Automated intelligent systems for visually impaired people are an advanced method for improving accessibility and promoting independence [1]. These systems utilize a blend of artificial intelligence (AI), computer vision, and sensory input technologies like internet of things (IoT) to offer immediate aid and assistance to persons who have visual impairments. A number of advancements in IoT technologies have the potential to greatly enhance blind people's safety and quality of life [2]. These systems strive to enable users to overcome obstacles and interact more effectively with their surroundings, whether it is through voice-based interaction, tactile feedback, or augmented reality interfaces [3]. The IoT can significantly improve the quality of life and autonomy of those who are blind or visually impaired. This is achieved by granting them increased access to information, enhanced safety and navigation, and improved communication abilities [4]. IoT navigation devices can enhance the mobility of visually impaired individuals by facilitating their movement in both indoor and outdoor settings [5]. Global positioning system (GPS)-integrated navigation offering step-by-step voice navigation through their smartphone, where IoT systems in conjunction with GPS may safely direct the users to their target place without any trouble. Beacons and sensors deployed in public areas can offer up-to-the-minute data regarding the environment, including the precise positions of entrances, elevators, and restrooms [6]. IoT-enabled navigation apps can offer precise directions and notifications regarding potential obstructions or risks in outdoor settings [7].

An assistive technology called the Mobi Stick was created to help people with vision impairments safely and independently navigate their environment [8]. It enhances the usefulness of the conventional white cane by combining cutting-edge technology like sensors, communication modules, and the IoT. It serves as an example of how visually impaired people can be empowered by contemporary technologies, improving their freedom, mobility, and safety in a variety of settings [9]. For those who are blind or visually impaired, wearable technology [10] significantly improves their safety, freedom, and quality of life. To overcome the difficulties posed by visually challenged users, these devices incorporate cutting-edge technologies including the IoT, sensors, AI, and haptic feedback [11].

Object detection is a concept that has been around there for a long time. Object detection can be aided by techniques such as edge detection, corner detection, and color-based segmentation, GPS based system, and Guide dogs. However, the main drawback of these systems was that they could only be used for a certain object and required a great deal of monitoring [12]. Researchers began utilizing machine learning approaches to recognize objects as computing power and data availability increased. They created the final model by applying statistical models and training to update its parameters. Researchers used a deep learning technique to detect objects, thereby dramatically increasing the accuracy of object recognition [13].

The topic of neural networks for object detection is a fascinating topic that will be explored. An important organ of the human being is the eyes. A spot observation divulges the predominance of visual information in our surroundings. Considering the modern era, and revolution in technology we try to introduce equipment that can help to face the daily life problems of visually impaired persons [14]. Assistance is needed to make their life easy and comfortable. Visual loss is inconvenient for their safety while using autonomous mobility or traveling. People with impairments have more challenges during self-navigation in new environments. People with vision problems will benefit from smart systems that combine IoT and AI to increase their safety, independence, and quality of life. Numerous opportunities, including autonomous navigation robots, real-time danger prediction, and adaptive help catered to individual needs, are made possible by artificial intelligence of things (AIoT's) mix of predictive AI with networked IoT technologies [15]. AIoT contributes to the creation of smarter, safer settings for blind people by integrating real-time data and continuously learning.

The main goal is to support people, who have vision difficulties by connecting the study called "on time audio alert automated intelligent system for visually impaired people". Proposed system equipped with hardware components namely Raspberry Pi processor, camera, earphone, voice module, and sensor. Objects can be captured via camera. Distance calculation would be done through an ultrasonic sensor and commands would be given through the voice module. However, the wired earphones would provide the final output to the vision-impaired person.

2. REVIEW OF PAST APPROACHES

There are a few IoT-based concepts for assisting blind people in India. The developed world employs a variety of technologies to assist blind people in living a comfortable life. However, in developing countries such as India, there are very few facilities available for visually impaired people that promote a normal lifestyle. Several related works in this field of visually impaired people projects were investigated and are described below. An embedded device with a robust obstacle detection algorithm that provides useful comments to users via audio actuators and vibrotactile. Field-programmable gate array (FPGA)-based 3D camera is extremely small and it can run for hours on a single charge [16].

With the help of the camera, objects will be captured and R-CNN modules with deep learning on the device itself used for image processing and detection. However, the final product would be transmitted to the visually impaired person's ear via an earphone [17]. Reading the object and taking the picture with the camera, change the image into greyscale. It converts text to audio. Finally, it gives the output as a voice message [3]. The several ultrasonic sensors that make up the obstacle detection system are arranged at various angle values. They calculate the distance gap between the cane and the ground as a result. Three types of topography are identified from the sensor data: level ground, small holes or pits, and staircases [4].

Smart glasses built-in camera takes a picture of the surroundings, which is then processed using Azure cognitive services called custom vision application programming interface (CVAPI). The user wearing Google glass can hear the output [5]. The algorithms were responsible for two key tasks: i) detecting and classifying crosswalk signals and ii) directing users to their desired location (across the target crosswalk) classification of RO, tracking navigation module visual-inertial odometry with geometry constraint path planning and audio feedback [6]. The proposer of this system constructed these glasses using an Arduino Pro Mini MCU, an ultrasonic sensor, and a buzzer to sense the distance of an object in front of them and beep to warn the wearer (user) that something is in front of them. The efficient smart glasses are made with the IoT can also be embedded with sensors and assist in object detection by covering a broader region [14], [18].

The obstacle detection module is comprised of an ultrasonic sensor, a control module for processing, and an output unit consisting of a buzzer [19]-[22]. The user can select a destination from a list of options in the memory that will cause the stick to travel in a different path. An ultrasonic sensor, sometimes known as a headphone, is employed in this system, along with a programmable interface controller (PIC) controller and a battery to guide them in the required path. The smart glasses operate on the principles of IoT and the Sonic wave mechanism. When a person or object enters view of the glasses, the Espeak module notifies the user of the distance gap between the entities. Display module must recognize the person's face using the Face dataset folder and either displays a name or display an unknown. The Smart Glasses are powered by a 5V battery and run Python 3. Real-time object detection using deep learning is utilized to distinguish between moving and stationary items. After detection, the motion model is determined by using a multi-object Kalman Filter tracker to track the objects through time.

HEADLOCK is an optical head-mounted display navigator that helps visually impaired persons navigate large open spaces by allowing them to hold onto landmarks across the space, such as a door, open fields, or other objects, and then giving oral feedback to lead the user toward the landmark [23]. To quantify accuracy and performance, a system is constructed and tested in this study utilizing two alternative algorithms, you only look once (YOLO) and YOLOV3. YOLOV3 Darknet model and YOLO Tensor flow _SSD _Mobile Net model are both used. The statements were converted into audio speech using the Python module in order to receive audio response from Google text to speech (gTTS).

3. PROPOSED SYSTEM

Proposed task is primarily intended to assist people who are visually impaired or have no vision at all. Because of technological advancements, we must be tapped to assist blind people. The next future and the future of technology are dedicated to serving people and assisting them in their daily lives. The proposed system's main idea is to make visually impaired people aware of their surroundings. This system is used to guide people with vision loss, partially sighted and completely blind, through the use of audio commands. This device is built with IoT technology, which includes a smart glass embedded with an ultrasonic sensor, a Raspberry Pi, a voice module ISD 1820, and a Bluetooth device (earphones). This device provides audio guidance to the user. Single-shot detector (SSD) is a fully convolution method for finding all the objects present in the image in one pass. SSD uses a grid cell to divide the image where each cell detects the object by forecasting their class and location. The grid cell determine object to be detected. To detect multiple objects anchor boxes and receptive fields are used. After dividing the image using a grid, for detecting objects it highlights the object. The SSD architecture allows a predefined aspect ratio to find the objects [24], [25]. Another parameter called zoom level through which can specify the number of anchor boxes to be zoomed (scaled) up or down concerning the grid as not all anchor boxes are necessary to have the same size as the grid.

Pyttsx3 is a text to speech (TTS) conversion library written in Python. It works with both Python 2 and Python 3 and works offline. The purpose of TTS is to convert chore text to audio. A simple, free freeware voice synthesizer for Windows and Linux that can speak English and other languages is called eSpeak. TTS requires a speech synthesizer to read digital text aloud. "Format synthesis" is a technology used by eSpeak. The technology makes it possible to have many languages available in a small container. Although device speech is clear to understand and fast, compared to larger synthesizers that are based on genuine speech recordings, it lacks the naturalness and fluidity. The following subsequent sections provides the details of system design, applied with the proposed model.

3.1. System design

System design has shown in Figure 1, contains the components camera, SD card, ultrasonic sensors, Raspberry Pi, relay, vibrator, and headphone. It play the main core of the concept. It needs below mentioned details of hardware and software.

3.1.1. Hardware

The complete hardware specification of system design contains Processor-Intel Dual Core, RAM 2 GB, ultrasonic sensor, Raspberry Pi, and Pi camera. It is the fundamental platform for application on which application is executed with suitable software.

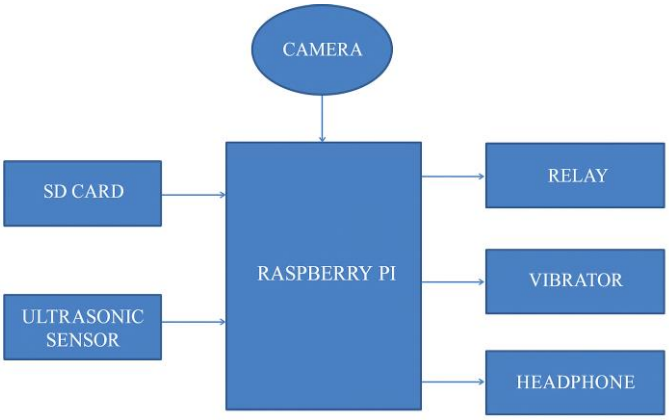

Figure 1. System design

3.1.2. Software

The next essential component of system design is software, where Language-Python, Tools-Thoony IDE, Operating System-Windows 7, 8.1, and 10 can used for application.

3.2. Raspberry Pi 3 model

The Raspberry Pi 3 model B structure has shown in Figure 2, credit card-sized device used for a multitude of functions, is the third version of the Raspberry Pi. Replaces the Raspberry Pi 2 model B and the original Raspberry Pi model B+.

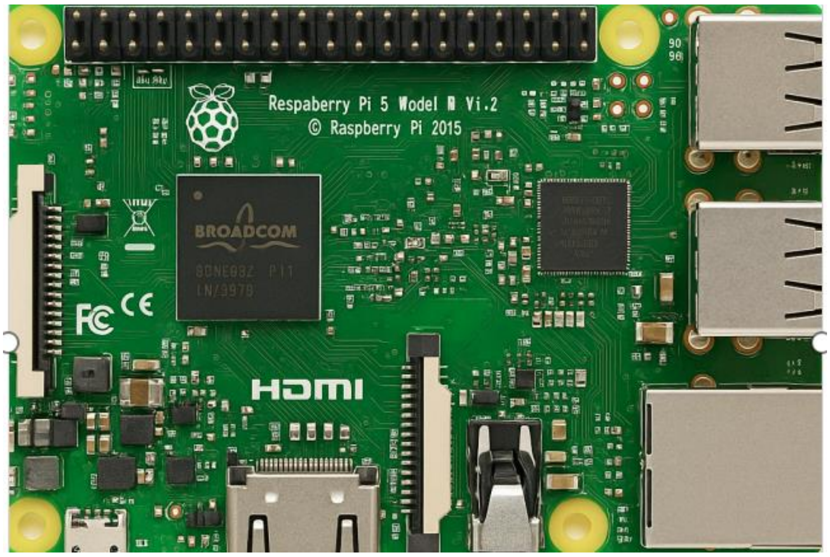

Figure 2. Raspberry Pi 3 model B

The third generation of the Raspberry Pi is called the Raspberry Pi 3. The Raspberry Pi 3 is backwards compatible with the Raspberry Pi 1 and 2 and shares the same form factor as the preceding Pi 2 and Pi 1 model B+. The Pi 3's ability to retain the Pi 2's form, connections, and mounting holes is its strongest feature.

3.2.1. Aspects

The important features of this equipment are CPU with 1.2 GHz 64 bit, Wireless LAN 802.11, Bluetooth- 4.0, Bluetooth low energy (BLE), RAM -1 GB, and GPIO pins-40 ethernet port.

3.2.2. Applications
It has many applications few listed here. It is used in server/cloud server. It play role in security monitoring and environmental sensing like (weather station) IoT applications. It used in robotics access point for wireless internet server for printers.

3.2. Pi camera port
The Raspberry Pi camera module shown in Figure 3 is capable of taking high-resolution still images and videos. Beginners will find it easy to use, while advanced users wishing to enhance their knowledge will find it useful. Numerous examples of people utilizing it for slow motion, time-lapse, and other video effects can be found online. A 5MP CMOS camera with a fixed-focus lens that can record HD video and still photos is the Raspberry Pi camera module. A video can be recorded at 30 frames per second in 1080p, 60 frames per second in 720p, or 60 or 90 frames per second in 640×480. Still, photos are recorded at a resolution of 2592×1944. The preferred operating system for the Raspberry Pi, Raspbian, is compatible with the most recent version of the camera [7].

3.3.1. Aspects
The important features of this equipment are sensor 5MP, Greater field of vision, capable of 2592×1944 stills,1080p30 video compatibility, 1080p video, CSI size: 25×20×9 mm, superior performance OmniBSI technology (high sensitivity, low crosstalk, and low noise) in a 1.4 m×1.4 m pixel Often, a 1/4" optical size is utilized. Image control functions that are done automatically: attempting to control the exposure automatically (AEC), white balance is automatically updated (AWB) scanning by band automatically (ABF), automatic luminance detection at 50/60 Hz, calibration of the black level automatically (ABLC), programmable controls include frame rate, cropping, windowing, panning, rear view and flip, AEC/AGC 16-zone size/position/weight control, and cropping. A parallel output interface for digital video is called digital video port (DVP), 32-byte embedded OTP memory is programmable just once.

3.3.2. Applications
The applications are yields a compact and versatile imaging solution, to remotely monitor environments or equipment, such as monitoring weather conditions, tracking wildlife, or checking the status of a 3D printer. It can facilitate virtual meetings, online classes, or telemedicine consultations. It is used for photography and time-lapse photography projects.

3.4. Ultrasonic sensor
An ultrasonic sensor shown in Figure 4 is a tool that measures an object's distance from it using sound waves. By generating a sound wave at a certain frequency and then monitoring for the wave to return, it can measure distance. The distance measure between the sonar sensor and the object is determined by measuring the time travel between the sound wave being emitted and the sound wave returning.

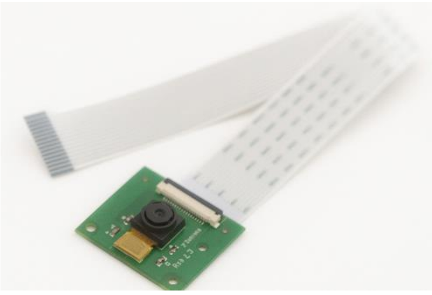

Figure 3. Pi camera

Figure 4. Ultrasonic sensor

Arduino code sends out a pulse from the trigger pin and measures the time it takes for the pulse to return on the echo pin. It then calculates the distance based on the speed of sound in atmosphere and prints the result to the serial monitor. The distance can be calculated using (1):

$$\text{Distance} = \frac{1}{2} \times \text{Speed of Sound} \times \text{Time} \quad (1)$$

where distance is distance to the obstacle, speed of sound is speed of sound in the air, and time is the time taken for the sound wave to return.

As the ultrasonic pulses leave the ultrasonic sensor and return to the transducer, they are measured. The sound waves from the transducer are reflected by the item and then returned to it. After generating the sound waves, the ultrasonic sensor will transition to reception mode. The time interval travel between sender and receiver is directly correlated with the distance between them. The ultrasonic transmitter will begin the timer after emitting an ultrasonic wave in single direction. When it encounters impediments, ultrasonic diffused through the air and returned instantly. When the ultrasonic receiver receives the reflected wave, it will eventually stop timing. The sensor's distance from the target object is calculated. It offers superior non-contact range detection with high precision and steady reading in an intuitive packaging [26]. Its performance is unaffected by sunlight or dark materials. A 5 VDC power supply is used to power the sensor. The sensor contains two pins that give digital input trig and echo that are connected to the controller.

3.4.1. Aspects

The important features of this equipment are operating voltage: 5 volts, current in quiescence: 2 mA, 15 mA of working current, range of detection: 2 cm to 4.5 m, pulse width of the trigger input: 10 us.

3.4.2. Applications

It has many applications, specifically used for navigation by robotic systems, help to avoid stumbling blocks, and used in engineering instruments for measurement, and control system for industry.

3.5. Methodology and module description

The proposed model consists of the following modules named as obstacle detection, identifying object by names and delivering audio alert. All modules work flow has been completed through convolutional neural network (CNN) with an SSD algorithm.

3.5.1. Single-shot detector

The system consists of the core components, namely a backbone model and an SSD head. The backbone is a neural network of pretrained type used for image categorization. It help to determine feature from input. ResNet network that has been trained on ImageNet and its final fully connected classification layer is dropped. The ResNet34 architecture produces a set of 256 feature maps with dimensions of 7×7 for each input image. SSD head consists of more convolutional layers that are appended to the backbone model. Outputs are interpreted as the bounding boxes and classes of objects in the spatial position of activation of the last layer. The diagram shown in Figure 5 illustrates the initial layers (depicted as white boxes) which serve as the backbone, while the final layers (depicted as blue boxes) correspond to the SSD head.

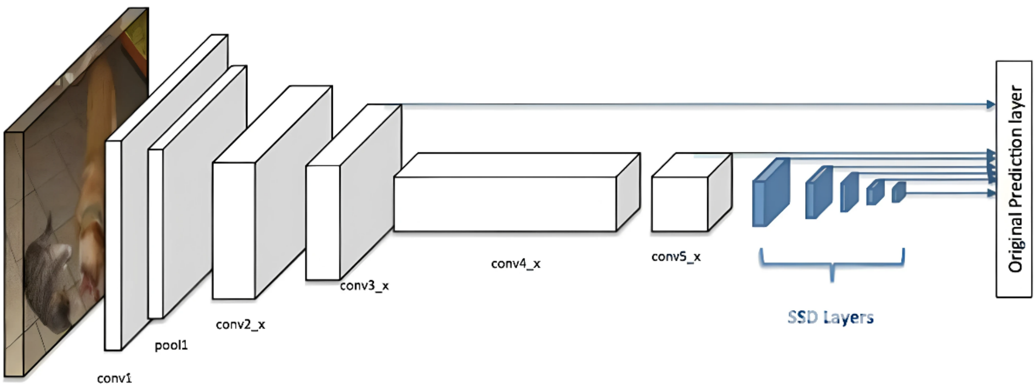

Figure 5. Architecture of a CNN with an SSD detector

a. Grid cell and anchor box

SSD splits the image with a grid and each grid cell be responsible for detecting objects in that region of the image. The word discovery objects inhibit prognosticating the class and position of an object within that region. However, we consider it as the background class and the position is ignored, if no object is present. For case, we could use a 4×4 grid is shown in Figure 6. Each cell is suitable to affair the position and shape of the object it contains.

Each grid cell in SSD is assigned with multiple anchor/previous boxes as indicated in Figure 7. These anchor boxes are pre-defined and each bone is responsible for a size and shape within a grid cell. For example, the swimming pool in the image corresponds to the high anchor box while the structure corresponds to the wider box. SSD uses a matching phase while training, to match the applicable anchor box with the bounding boxes of each ground verity object within an image. Generally, the anchor box with the loftiest degree of imbrication with an object is responsible for prognosticating that object's class and its position.

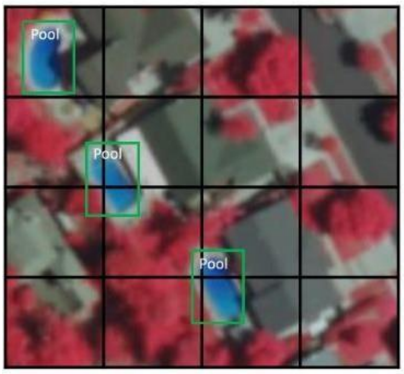

Figure 6. 4×4 grid

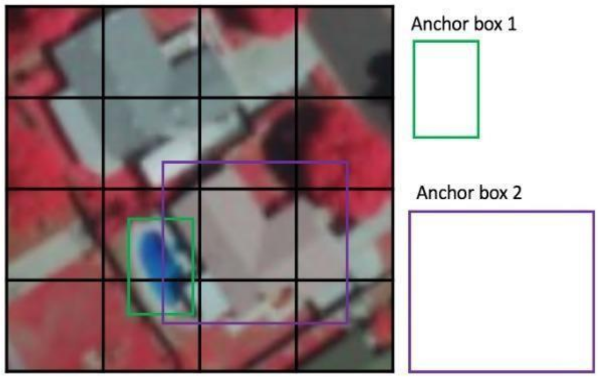

Figure 7. Anchor boxes

b. Receptive field

The SSD architecture relies on the main idea of receptive field to detect objects at different scales and provide accurate bounding boxes. It refers to the specific area in the input space that a particular feature of a CNN is to be focused on. Perform convolution on the middle layer and obtain the top layer (2×2) where each feature corresponds to a 7×7 region on the input image. They are formed by applying the same feature extractor at multiple positions of the input map in a sliding window fashion. Features within a given feature map possess identical receptive fields and search for identical patterns, but at different locations. It is responsible for the spatial invariance observed in ConvNet.

The ResNet34 backbone generates a set of 256 feature maps with dimensions of 7×7 for each input image. When a 4×4 grid is specified, the most straightforward method is to do a convolution on the feature map and transform it into a 4×4 grid. The additional step performed by SSD involves applying multiple convolutional layers to the backbone feature map. Convolutional layers produce object detection outputs. As a result, SSD enables us to establish a system of grid cells organized into several tiers. For instance, a 4×4 grid can be employed to locate tiny things, a 2×2 grid can be used to locate mid-sized objects, and a 1×1 grid can be utilized to locate objects that encompass the whole image.

3.5.2. Module description

It consists of the modules named as obstacle detection, identifying object by names and delivering audio alert. First detection of object is determined with help of grid cell and anchor box associated with SSD. Then detected object is named with OpenCV. Third detected object is conveyed to user through audio alert with help of experimental setup. Detailed information is discussed in next section with associated examples.

4. RESULT AND DISCUSSION

A Pi camera captured the object and the object is detected using the SSD algorithm. It detects the object using grid cell and anchor box. Its aim is to predict the class and location of the object. The names of the obstacles discovered are displayed to the user. Based on the Class Id's the names of the obstacle is shown in Figures 8 and 9 with experimental set up.

The trained dataset contains 15 objects as shown in Figure 10. And also displays total number of images in the data set. In training, CNN allocates labels for the object. So, can easily identify object in image.

Figure 8. Experimental setup

Figure 9. Object detection

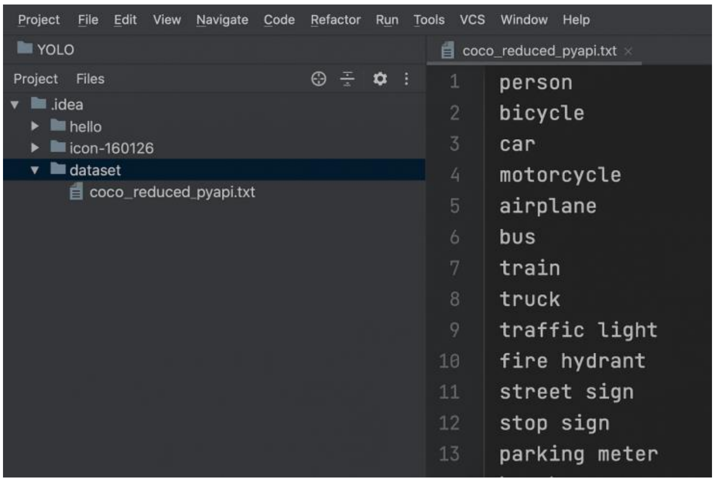

Figure 10. Trained object list

With the object name, the accuracy of the detected object is also displayed to the user. When the particular threshold is met the accuracy is calculated and shown in Figure 11. Object is detected and audio is given to the user with help of TTS Library associated with Pyttsx3.

Figure 11. Identification of object by name-tested output-CUP and REMOTE

Pyttsx3 is given the obstacle names as input. It is essentially a TTS conversion library. TTS's purpose is to convert text to audio. The speech synthesizer used is eSpeak. TTS necessitates the use of a speech synthesizer to read aloud digital text. A simple, freeware voice synthesizer for Windows and Linux that can speak English and other languages is called eSpeak. eSpeak employs a technique known as "format synthesis".

4.1. Comparison study

The proposed system behaviour is compared with existing technologies available in real world like white cane, Guide Dogs, and GPS based systems and wearable assistive devices. Figure 12 shown below that illustrate comparison of proposed system with various existing technologies in different feature circumference like real time obstacle detection, audio alerts, environmental awareness, indoor/outdoor usability, ease of use, hands-free operation, maintenance requirements, cost, and user independence.

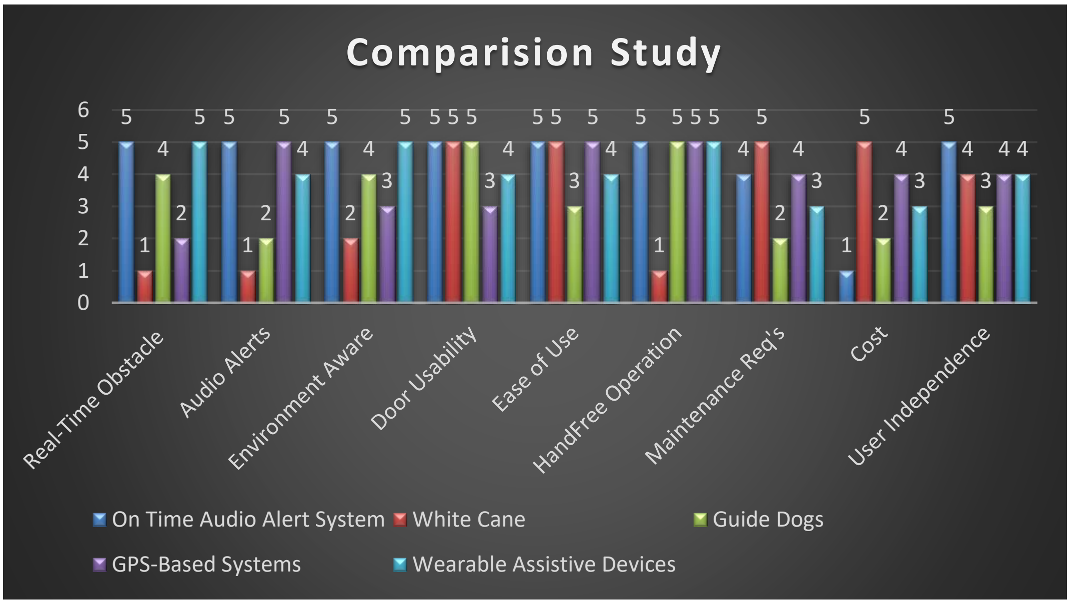

Figure 12. Comparison study with existing technologies

5. CONCLUSION

The basic goal of the proposed system was to create an obstacle detection system for visually impaired pupils and convey name of obstacle with distance to blind people. It is done using ultrasound sensors, Raspberry Pi, and smart glasses. This intelligent system allows people with disabilities to move freely. It provides low-cost convenient smart glasses for users in real-time circumstances. It recognizes objects in both outdoor and indoor environments. Objects are detected using ultrasonic sensors in the front, left, right side, and surface directions. To recognize objects, the SSD is used. The system transmits an audio instruction to the user via wired headphones. It can only detect only on trained 15 objects alone. At the moment, the system weighs a few grams, wires connect all of the components, which has increased the system's size. These can be used for social benefit and improvement through cutting-edge technology and outside-the-box thinking, thereof changing the lives of millions of visually impaired people around the country. Future work will concentrate on improving the performance, and this device will be able to detect ground, small holes, and staircases. Another notable enhancement could be a system modification based on feedback from visually impaired people.

ACKNOWLEDGEMENTS

Authors the acknowledge the support of person named Abitha and Bhuvaneshwari on this study.

FUNDING INFORMATION

Authors state no funding involved.

AUTHOR CONTRIBUTIONS STATEMENT

This work follows the Contributor Roles Taxonomy (CRediT). The specific contributions of each author are detailed below:

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
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Sumathy Vethanayagam	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Sundararajan Geetha	✓	✓			✓	✓	✓			✓	✓		✓	✓
Brahmadesam Viswanathan Krishna	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee.

DATA AVAILABILITY

Data availability is not applicable to this paper as no new data were created or analyzed in this study.

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