AI Based Pilot System for Visually Impaired People

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Abstract— **In today's world we live with visually impaired people struggling to do things at their full potential as they lack sight of the environment they live in. Affected individuals are often seen with slips, trips and fall over light obstacles on their walkway. To some extent, these blind people cannot relate to any objects they come across such as cars and people around. As technology evolves, there has been numerous attempts in solving this problems for the affected group of people and the proposed solutions need further improvement on how to effectively assist the affected individuals to navigate from one place to the other using real-time updates of their whereabouts. This paper presents the design of an intelligent walking stick for the blind using Raspberry Pi 3 b+ as a central microcontroller, Ultrasonic sensors and Global Positioning System (GPS). The ultrasonic sensors are used for scanning the environment on walkway and sideways using sound waves at certain defined distances, and GPS module is used for real time directions and navigation. It also contains Bluetooth-headset that is used for the audio navigation through the aid of interpretation from the real time feed of ultrasonic sensors and coordinates from the GPS, thereby giving the user the actual route and possible turns until the destination point. Special emergency messages using keywords of the location coordinates obtained through GPS are sent via SMS subscription account connected to the GPIO pins of the Raspberry Pi to care-givers for tracking purposes when required. The entire setup of the intelligent walking stick makes navigation and tracking possible, thus effectively assisting the visually impaired people.**

Keywords— Artificial Intelligence (AI), Bluetooth, CNN, GPS, Raspberry Pi, Short Message Service (SMS), Ultrasonic Sensors

I. INTRODUCTION

Visually impairment is a state of not or less identifying objects on the surrounding making it practically impossible or difficult to make informed decisions thus affects one's confidence to navigate effectively to their desired destinations, having that said 90% of human decisions are taken from eye sights to brain for processing and making informed decisions. Shortly people with limited or no eye sight are classified as disabled. Previously such people were dependent on traditional sticks which were not avoiding obstacles, [1] trained dogs and family members to walk them which needed training and limited their privacy.

The statistics recently presented by [2] and [3] World Health Organization proves that 1.96% (1.3 million) of world's 7.7 million population is visually impaired therefore there is a greater need to solve for such challenge and this is justified by South African statistics [4]. The existing ETA designs around the same context noted more short-comings highlighted, efficiency and cost being the leading factors as details proves that the challenge is mostly faced by the disadvantaged group in the world where affordability is an issue. Others have used generic object identifiers and these are sometimes confusing to the users [5]. The size of the design matters to afford usability, height of the stick needs to be adjustable to suit users, yet the existing designs are just static. GPS module was only used on safety or emergency conditions to decode the location in [6]. Yet the need is ultimately a consistent update to the user approximately 95% of the time. The solution uses speakers of which are very loud and creates discomfort in public and can expose the user to all sort of robberies. The need to improve on the usability, effectiveness and portability of the aid is highly needed. With newer hardware technologies and more accurate sensors in place to get at-least 90% of the human behaviour modelled through technology, this study presents carefully designed intelligent walking sticks with improved usability, effectiveness and portability for visually impaired people.

The subsequent sections of the article are detailed as follow: the literature-review where an in-depth of what other people have done on the same study is in section II, then the methodology employed in this paper is presented in section III. The results of the designed system is presented in section IV while the conclusion is drawn in section V.

II. LITERATURE REVIEW

In time past, visually affected group were dependent on families, friends and trained pets to walk them around. The availability of these people to help the affected group is uncertain on daily basis which makes the unreliable. Pets such dogs sometimes need some medical attendance and they are expensive to train. In order to solve these limitations, various automated devices have been designed solve for the visually impaired individuals. Several studies have been conducted on the concept of solving the problems of visually challenged people. TensorFlow machine learning approach was presented in [7],[8] for several object detection. Eluvathingal et al. [9] implemented an advanced walking stick for visually impaired using the concept of "*Haar Cascade like feature*", leaving the dark portion to predict the image. This model has the inability to distinguish an object in multiple selections. It also used the GPS module to locate the user in case of emergency unlike giving a consistency update to visually impaired users to ensure they reach destination. D'souza et al. [10] proposed an autonomous walking guiding stick for the blind using echolocation and Optical Character Recognition (OCR) using images with text written on it to provide feedback to the user. The approach however has some limitations in solving the problem of object detection for visually impaired people [11]. The users, who are visually impaired people, can be at risk of taking wrong decisions when the model fails to read any text on hazardous objects to their well-being. Every object should be detected and be only informed of selected objects that can be of risks to the visually impaired people. The procedure of training new objects on a live capture will delay the user as it will take time to do the comparison [12]. Sahoo et al. [13] designed a walking stick that partially solves the problem of

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the visually impaired individuals However, in [14] GPS was only used for emergency conditions while the navigation is only taken care by the use of ultrasonic sensors. In such situations, the user only get notification of objects on the surrounding while they are not certain of the environment in which they are walking. While it perfectly works for avoiding on floor objects, the challenge remains the inability to accurately identify the objects around them.

Khyam et al. [15] describe the range at which an ultrasonic sensor works and further employed a server motor to detect objects from far also supported by [16] and [17]. This approach failed to solve real-life problems as the visually impaired people lives in among different people with various activities in the society. This is because the solution does not solve for navigation from one place to another but only focuses on scanning the objects around the user and providing feedback through audio [18]. Hence systems designed for such people should accommodate these peculiarities in the environment in the designs of the walking sticks. It should help them navigate their movement and as well update their current location in real-time. Erichsen et al. [19] implemented the machine learning frameworks for object detection using Tensorflow. This facilitates the training of the models while the classification is done using the features extracted on related images [20]. Although the object identification works effectively, the navigation needs further improvement.

III. Methodology

This section presents the detailed description of the foldable intelligent walking stick designed in this study. The foldable intelligent walking stick has a wheel to push around to ease the weight 0.65kg. TensorFlow deep learning as presented in [7],[8] for object detection, is also implemented in this paper to train models of interest. The system has a high level of artificial intelligence where a user converse with the system by defining the destination through speech inputs as commands. The proposed designed system is made up of different components namely hardware and software (made up of artificial intelligence). This is followed by the integration of both hardware and software components.

A. Complete System breakdown

The block diagram of the proposed system is described in Fig. 1. The carefully designed block diagram contains the features of the proposed intelligent walking stick for visually impaired people. The system utilizes the information of the initial location and final destination of visually impaired people, and as well considers the real time update of information along the route from initial location to the final destination. It also considers the users' need of awareness with regards to the detection and identification of the different surrounding objects on the floor surfaces to avoid unnecessary injuries along the route from initial location to the final destination. The need to create informed awareness, of the different identified surrounding objects, in the visually impaired people is also considered in the block diagram. This will enable them to decide on how to handle the situations at hand. Emergency situations are also handled as emergency text with the current location computed in real-time are sent to caregivers.

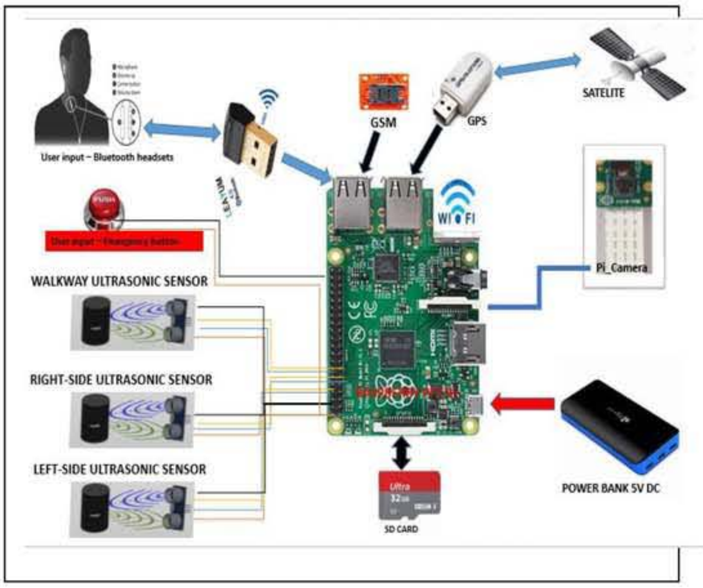

Fig. 1: AI Based Pilot System – Block Diagram

B. Hardware

The main hardware unit of the system is the Raspberry Pi 3 B+. It is the hardware unit that houses all the programming instruction codes and control flow used in the system. It has an SD card as the hard-drive that holds the operating system. It also has USB ports and GPIO pins to connect peripherals. Raspberry Pi Camera is attached to the Raspberry Pi slot to stream and capture images in real-time. A 5V, 1.8 Amp power bank is used to power the system. A Bluetooth is also connected to the USB ports and it is used to interface the headsets and microphone with the sound drivers of the Raspberry Pi. A GPS module is connected to the USB ports as well, making it possible to decode the location coordinates of the visually impaired person in real time and used for purpose of direction navigation. The emergency reserved key words that sends an SMS to the caregiver in case of emergency is attached and connected to the GPIO pins. WI-FI dongle connected to the system ensures that the GPS decodes the location coordinates in real-time and ensure that messages are sent to the care-givers using the http post protocol to the account we signed on. Lastly, ultrasonic sensors are connected to facilitate the detection and identification of the different surrounding objects on the floor surfaces to avoid unnecessary injuries along the route from initial location to the final destination.

C. Software

The entire software component of the proposed system is developed using Python programming language containing different independent scripts and the main script that controls the flow and the calling of the different library functions used in this system. Protobuf is used to build the Tensorflow on host during installation of the software on Raspberry Pi.

OpenCV – This is a programming platform containing several libraries of functions used for handling computer vision problems in real-time. It facilitates the real-time streaming and capturing of images needed to detect and identify different objects along the route from initial location to the final destination.

Tensorflow – This is a machine learning platform that aid in facilitating the creation of large-scale convolutional neural network (CNN). This was used for the image processing through manipulation of the images such as noise with background removal and the building of training model and classification of the different images of objects.

Google Cloud **Speech API** – The wi-fi facilitates the connection to Google's cloud API for speech-to-text and text-to-speech engines. It ensures proper transmission of the information obtained from GPS.

D. Integration

The Integration of the entire system, that is the hardware component and the software component, is then implemented. It consists of the ultrasonic sensors for detecting object on the walkway and feeds data or output through the Raspberry Pi GPIO pins. It gets interpreted in simplified text that a user can understand. It then channelled through the Bluetooth protocol to headsets as speech. The objects are captured in real-time using OpenCV and the objects are identified using the training and classification model on Tensorflow. This is then sent through the headsets as a class name based on the categorization as defined during training.

The GPS module decodes a string from the satellite, and the location coordinates in real-time are used for navigation. A set of reserved words used as contents in times of emergencies are combined with location coordinates in real-time for composition of messages sent to the caregiver when required. The message is sent through the use of http post method in a form of an SMS. All the functional units of the complete system work together to make the intelligent system work efficiently.

The Raspberry Pi receives all the data inputs, deals with the processing of the data and sends out the outputs as expected with a script defined sequence, making it easy for the user to relate to the environment, and making informed decision.

E. Artificial Intelligence

To solve for the interfacing issue for visually impaired people, the critical issues of usability and affordability had to be considered. A text-to-speech and speech-to-text in google cloud API aids the users in communicating with the stick and get prompt feedback on desired functionality. Below is a sample of the conversation between the system and the user to start a desired journey. The input from the user into the system is achieved through the microphone, while the feedback from the system to the user is achieved through the headsets. It expects certain inputs vocal words, and validates inputs to ensure accurate functioning as requested by the user. This functionality is core and makes it possible for the visually impaired people to relate to life. The Google API for text-to-speech and speech to text is user-friendly.

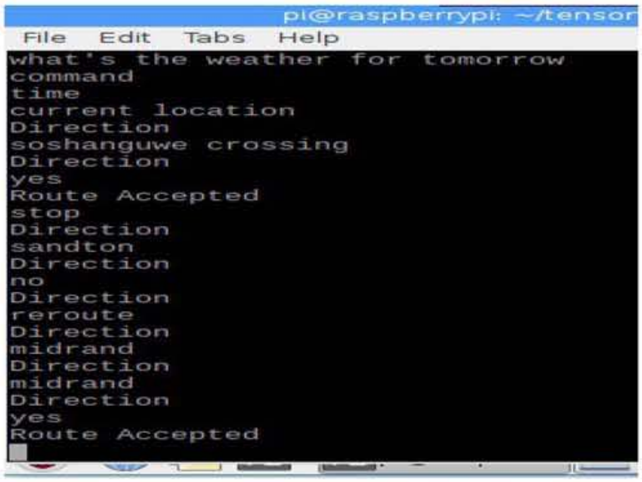

Fig 2: Artificial Intelligence

The functionalities provided or defined to operate the basic navigation uses a set of defined keywords to unlock them. So, the software controlling the hardware and sensors act as an API (Application Program Interface).

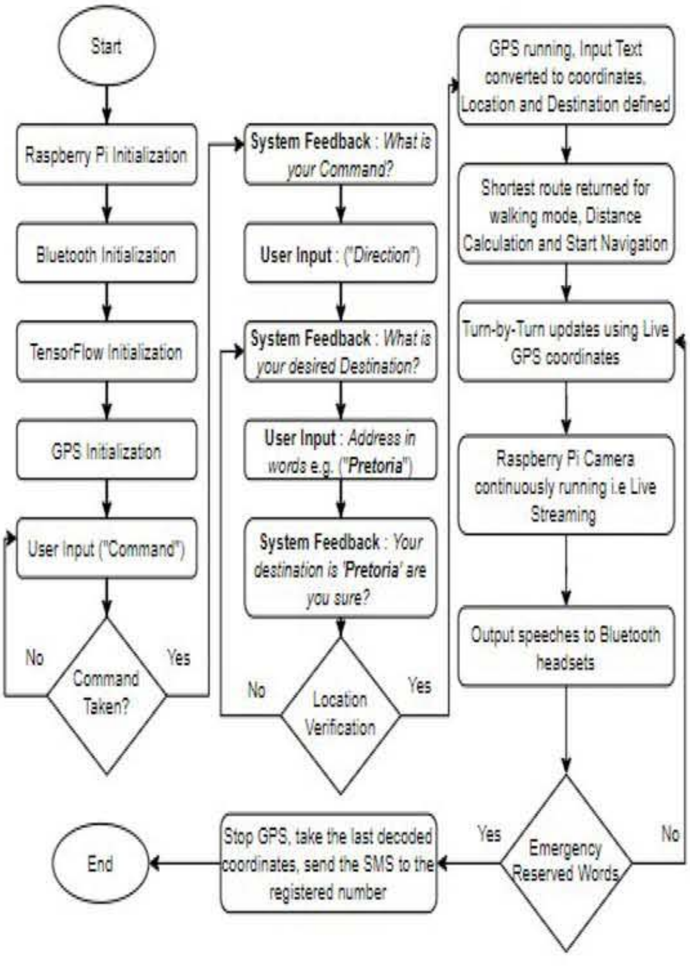

Fig 3: AI Based Pilot System - Flow Chart

F. System Algorithm

Algorithm 1: AI Based Pilot Navigation System for Visually Impaired

Input – **Uz** *as the ultrasonic sensor*, **RC** *as the Raspberry Pi Camera*, **V** *as the voice command,* ***S*** *as the state of the person,* ***OP*** *as the object, and* ***GPSm*** *as the GPS module.* ***EMG*** *as the emergency button.*

Output *–**Gr** as the navigation.* ***Vr*** *as response or feedback as voice command via headset.* ***Uzd*** *as the state when object detected on ultrasonic sensors.* ***RCd*** *as when object is detected on the camera.* ***GPSd*** *as when coordinates are decoded from the satellite.*

While (Movement = True)
  If (V = 1 and Vr = 1)
    #decode coordinate
    Decode(Coordinates)
  End:
  If (*GPS_d = 1*)
    #Updates location in real-time
    Updated(Location)
    #calculate distance between origin and destination
    Calcalated(Dist)
    #suggest shortest possible route
    Sug(Shortest_Reoute)
  End:
  If (Uz_d = 1)
    #Update the user with objects on the floor and the direction of the object with distance to it.
    Update(Sense_Object_&_Direct)
  End:
  If (RC_d = 1)
    #Tensorflow comparison and identify object by name
    Identify(Visual_Object_&_Direct)
  End:
  If (*EMG* = 1)
    #Compose emergency text with location in real-time
    Compose(EMG_Text_&_Location)
  End:
End:

IV. EXPERIMENT AND FINDINGS

A. Quality of Devices

Table 1 describes the different possible alternatives such as Pic-microcontrollers and Arduino, and how they differ from the Raspberry Pi selected in this paper for the proposed system. The table also provide the different properties of the Raspberry Pi such as internet connection, usable voltage, processing memory, interface options, input and output pins, default operating system (OS), preferred operation and accommodated peripherals. The detailed features of some of the afore-mentioned properties make Raspberry Pi the preference over the alternative shown on the table.

Table 1: Quality of Devices i.e. Raspberry Pi, Arduino and Pic Microcontroller[8]

Qualities	Raspberry-Pi	Pic-Micro-controller	Arduino
Internet Connection	Yes	Using Shield	Using Shield
Usable Voltage	5V	5V	5V
Processing Memory	512 MB RAM, Micro SD Card Slot	48 KB Flash Memory	32 KB Flash 2KB SRAM/1KB EEPROM
Interfacing Options	Ethernet, Wireless LAN, Bluetooth 4.1/BLE, I2C, UART, SPI	SPI, PSP, I2C, UART	SPI, UART, I2C
Inputs/Outputs Pins	40 GPIO Pins (No Analog and 8 Digital)	29 approx. 43 Pins (approx. 40 Pins, 13 pins are ADC Inputs, 10 bit grouping)	14 Digital pins (6 Pulse Width Modulation Output) and 6 Analog pins
Default OS	Linux	Custom	Custom
Preferred Operation	Software and Hardware	Hardware	Hardware
Accommodated Peripherals	Audio and Video connector	None	None

B. Ultrasonic Calculation

Ultrasonic sensors factors the speed of sound in distance calculation and the fact that they send and listens for echo thus doubles the distance travelled. In order to get the actual distance, the results needs to be divided by two. In this paper, we needed to get the distance in centimetres hence the constant is 34300.

$$\text{Duration} = \text{pulseIn(echoPin, HIGH)} \quad (1)$$

$$\text{Vin(echo)} = \frac{R1}{R1+R2}\text{Vin(vcc)} \quad (2)$$

$$Vin(echo) = \frac{2200ohm}{2200ohm + 1000ohm}5V \quad (3)$$

Vin(echo) = 3.4375V
Vin(echo) = 3.4 V

The above formulas in Eq. 1 to Eq. 3 produce a linear representation set of results. Measuring the actual distance using a ruler gives us the fine margin results from the distance produced by the sensors. Samples were used to draw the reading in Fig. 4 on random variation of values.

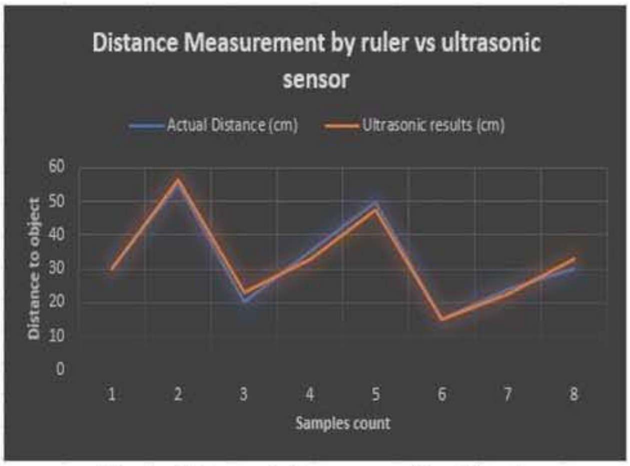

Fig 4 : Ultrasonic Sensor reading Graph

Fig. 5 show the detection of objects by the ultrasonic sensor. The floor level objects are detected on the 3 specified angles namely, ahead, left and right. The vocal output is sent through the headsets to inform the user so as to help them to make informed decisions.

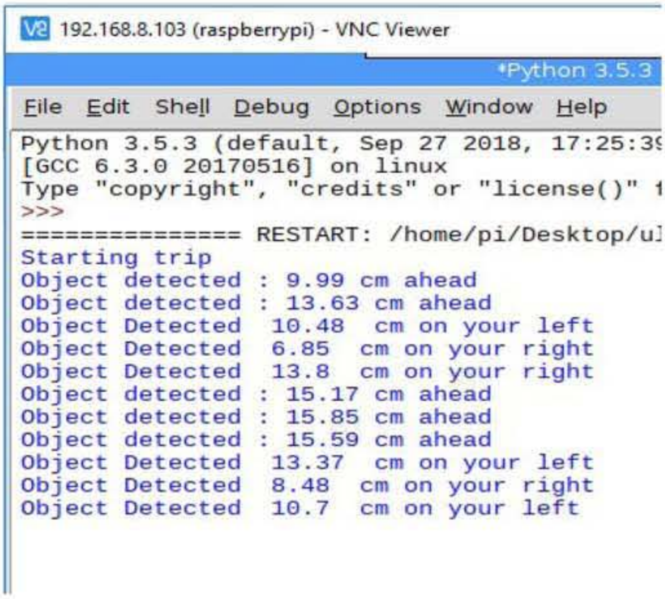

Fig 5: Ultrasonic Sensors Output

C. Vision-Based object-Detection

The vision-based object detection using machine learning approach is also used for the identification of the objects. It considers the object characteristics such as sizes, shapes and error dropped-out of each image depth. The approach utilizes the model that trains a series of independent images before the classification of the objects. CNN is applied. The convolutional layer contains the spatial size of fitting neurons to produce a classification and this is calculated using different parameters of a detected image such as the input volume size W, the convolutional layer neurons kernel field size of the K, the applied strides S and the amount of zero padding P used on the border. The fitting neurons is computed as:

$$FN = \frac{W - K + 2P}{S} + 1 \qquad (4)$$

The second layer deals with the redundancy or anomalies in a prediction to relate to a class of known objects. This improves the learning for accurate computations. The dataset used in this study are of different sizes for better categorization and classification, thus making efficient to classify them against the live captured visuals. The process loops through all the classes filtering each image according to size and black dots to predict the class each image belongs to. The training graph process showing how the normalization and filtering process is presented in Fig. 6 and Fig. 7.

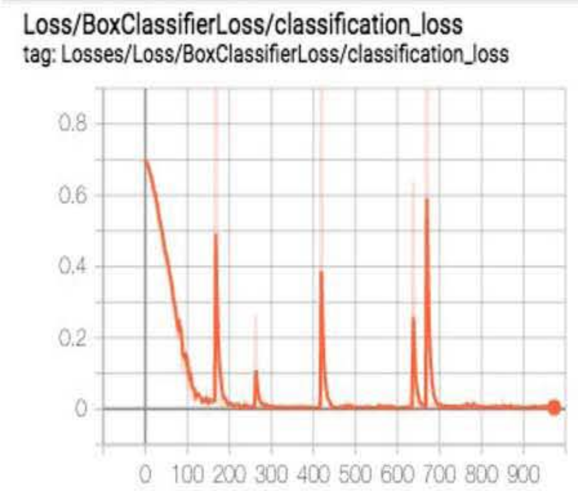

Fig 6: Classification of Data Loss

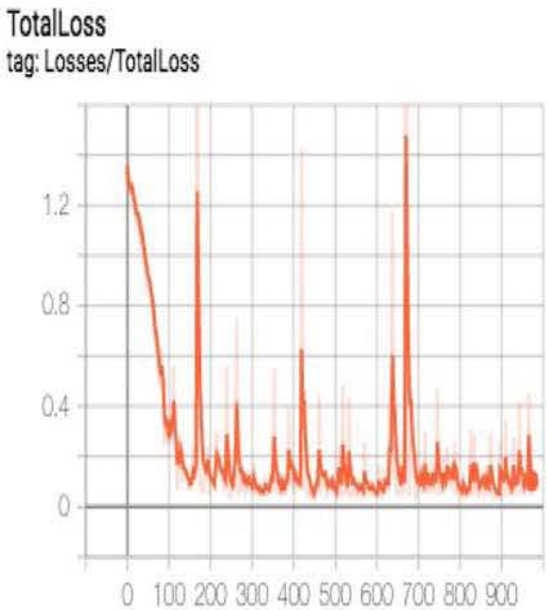

Fig 7: Total loss and Score calculation

The rectified linear unit shows the results of the normalized classes and classification are given an index. Each class is made of series or an array of related images that makes up a linear relationship. In order to predict a person, series of different images of people are considered. Different attributes of human beings are noted with the image size (see

Fig. 8). The process ignores the background because it has already been filtered. The image is then assigned a score to differentiate it from other images like cars and dogs.

Fig 8: Tensorflow Detected Objects

Fig 9: Final Design of the stick

The final product to be used by the visually impaired people is presented with all the components connected and functioning as a unit in Fig. 9. The proposed system works properly after it has been tested using different conditions. There are however a few limitation affecting the proposed system. Firstly, the GPS connection is affected by the clarity state of the location as either indoor or outdoor. Its operation is negatively affected when in a closed room where the GPS module is not exposed to the sky. Also, the GPS module fails to work properly when there is no internet connection. When the room is dark, the camera is faced with the problem of capturing a clear image, and this affects the image detection and identification. The weight of the complete design is 0.65kg with the battery lasting for six (6) hours when fully charged giving users enough time to walk to places of about 33 kilometres.

V. CONCLUSION

The design of an intelligent walking stick for the blind using Raspberry Pi 3 b+ as a central microcontroller, Ultrasonic sensors and GPS has been presented in this paper. The environment on walkway and sideways were scanned using ultrasonic sensors while GPS module was used for real time directions and navigation, Bluetooth-headset used for the audio navigation with the aid of interpretation obtained from the real time feed of ultrasonic sensors and coordinates from the GPS. These functional combinations of the system components assist the user to effectively navigate the route and possible turns of the visually impaired people until they get to the destination point. The proposed system provided special emergency messages via SMS using keywords of the location coordinates obtained through GPS in real-time to care-givers for tracking purposes when required. The proposed intelligent walking stick makes navigation and tracking possible, thus effectively assisting the visually impaired people.

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