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Raspberry Pi and White Cane Integration for Assisting the Visually Impaired

Aparicio Carranza[1], Anny Baez[1], Josue Hernandez[1], Harrison Carranza[2], Hossein Rahemi[2]
[1]New York City College of Technology of the City University of New York
186 Jay Street, Brooklyn, NY, USA
acarranza@citytech.cuny.edu, baezanny@gmail.com, josue.hernandez@gmail.com
[2]Vaughn College of Aeronautics and Technology
86-01 23rd Avenue, Queens, NY, USA Country
harrison.carranza@vaughn.edu, hossein.rahemi@vaughn.edu

Abstract **-** *There are at least 2.2 billion people in the world who have near or distant visual impairment according to data from the World Health Organization (WHO). According to the Perkins School for the Blind, only 2% to 8% of blind people use white canes. This is because 90% of them have accidents when using walking sticks. We have created a system to help the visually-impaired upgrading the white cane by implementing four essential elements: An electrical-setup employing a simple computer board (Raspberry Pi), connected to an HC-SR04 ultrasonic distance sensor that measures the distance to an object using ultrasonic sound waves, and voice feedback that alerts the owner of nearby objects via a speaker. Furthermore, a Raspberry Pi Camera for real-time object detection with a deep learning algorithm capability "YOLO" is used. The locations of these elements in the white cane are situated in the blind spots to avoid accidents to the owner.*

Keywords**:** Object Detection, Raspberry Pi, Visual Impairment, White Cane, YOLO

1. Introduction

Our senses are of great importance since they are the basic instruments of interaction with the environment for our survival. According to the organization ZEISS, the most important organ is our sight, where up to 80% of all our perceived impressions are through this sense, because the eyes are the best to protect us from danger [1]. Around the world, there are nearly 2.2 billion people who have near or distant visual impairment based on the data collected from the World Health Organization (WHO) [2]. Based on the Perkins School for the Blind, 2% to 8% of people who are blind use a cane for help [3]. This is due that 90% of accidents occur while using the walking sticks [4]. A system that is of great help for the visually impaired that takes the downsides of a white cane and rectifies them with four essential elements: a battery-powered circuit applied to a Raspberry Pi connected with an HC-SR04 Ultrasonic Distance Sensor and a Speaker, and real-time object detection with a Raspberry Pi camera using the deep learning algorithm "YOLO" was created.

A white cane in our society has become one of the symbols of a blind person's ability to come and go on his own [5]. While canes have existed for a long time, the use of a "white" cane in America is said to have come from a man who saw a blind man using a black cane, which was not visible to incoming cars. This prompted him to paint a cane white in order to be seen easily. The white cane we have used is a foldable long cane about 1 meter long when unfolded, it is held together with a bungee cord, so that it may be unfolded with minimal effort. It is made of aluminum to be sturdy while also being lightweight, so as not to be inconvenient to walk around with. In an effort to create a system that furthers the range of detection that can be achieved with the white cane alone while at the same time adapting to the ever-changing real world environment we have modernized the white cane and added new technology.

The Raspberry Pi is very economical and widely used microcontroller in the area of robotics. It is a computer the size of a credit card. It consists of a motherboard on which a processor, a graphics chip and RAM are mounted. It was launched in 2006 by the Raspberry Picon Foundation with the aim of stimulating teaching computer science in schools around the world. These types of cards are designed to be integrated into Internet of Things (IoT) projects or for automation. One of the particularities of these boards is that they require a specific expansion board to be able to program them. When they are already programmed, we can install them to carry out the tasks for which they have been programmed [6].

The application of the HC-SR04 ultrasonic distance sensor in connection with the simple Raspberry Pi computer is a low cost distance sensor that uses ultrasound to determine the assigned distance of an object [7]. If the ultrasonic sensor detects an obstacle, the Raspberry Pi records that signal and proceeds to voice navigation statements that are below the assigned distance condition. Voice navigation receives the signal and tracks an activated voice to alert the person through a speaker plugged into the Raspberry Pi audio jack.

The Raspberry Pi Camera is used to take high definition videos as well as still photos. We have implemented the framework for machine learning TensorFlow, the library for the computer vision OpenCV and a real-time object detection system YOLO [8]. The Camera captures the surrounding environment and the image is processed by the Raspberry Pi using OpenCV and passes through the YOLO configuration to be classified in the computer.

This paper provides an overview for how today's technology is used with a White Cane. The rest of this report is structured as follows: Section 2, focuses on different hardware components working in tandem with the software requirements, Section 3, describes how the white cane and other components are implemented, and our conclusion is presented in section 4.

2. Hardware and Software Utilization

The White Cane is incorporated with a Raspberry Pi in order to improve its effectiveness as a visual impairment aide. The Raspberry Pi is a compact computer running the Raspbian Operating Systems (OS) and has a microprocessor that is used to control other devices. The Raspberry Pi we used was fixed to a White Cane and integrated with an ultrasonic distance sensor and camera in order to recognize nearby obstructions and alert the user. The Algorithm YOLO is used with the camera in order to increase the object detection range and give a broader idea of the blind person's surroundings.

2.1. White Cane Background

White Canes are used by blind people to help them to have independence. It is used as a symbol to show others that they are blind. Currently, not many people use White Canes as a method for moving around, instead they prefer to use guide dogs and even guide persons. These methods are not without their own setbacks, like being allergic to dogs, which may make it hard for everyone to use the mentioned method. Over the times, technology has been used to improve all sorts of things of everyday usage. The modern day White Cane that is primarily used to show people around them that a person is blind is a perfect candidate to receive a technological upgrade. There are already laws in place for protecting people with White Canes and procedures to follow in order to use one. This means that any changes that we implement can be incorporated to rules and regulations that already exist.

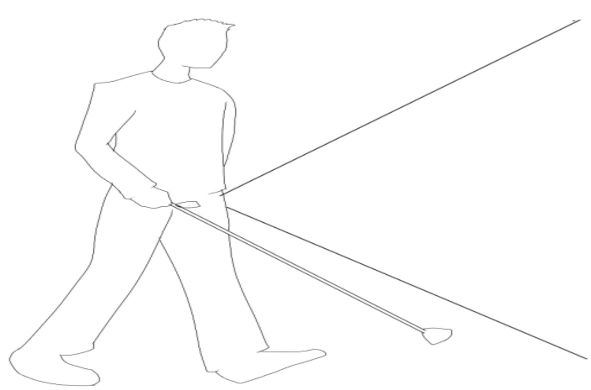

Fig. 1: Person using white cane with new range of detection shown

The reason that people are not using White Canes as much as it should is because many outside variables can give problems to White Cane users. It will not protect users from objects above the cane resulting in many head injuries to the person. Sudden changes to the blind person's surroundings can cause injuries due to the fact that the Cane user thought it was cleared and OK to keep walking. Other people are also a contributing factor to accidents, urban areas are more densely populated that would become harder to navigate in an incoming crowd of people, also people who do not care of what is in front of them can hurt blind people. Another issue concerning the White Cane is its size, which directly impacts how far ahead an obstruction can be detected. The average size of a cane is 1 meter long; therefore, it can only detect items 1 meter away. Moreover, the cane cannot be made any longer without creating inconvenience to others around, which makes it use more restrictive. A Raspberry Pi can be placed on the cane to correct some of these issues as seen in Fig.1.

2.2. Ultrasonic Sensor HC-SR04 and Speaker

The HC-SR04 Sensor or Ultrasonic Distance Sensor is designed to detect objects using ultrasound transducers. This sensor contains two horns, the emitter consists of one that emits an ultrasound sound that bounces off the object to be measured and the other horn is the receiver which is the one that receives the sound, as shown in Fig.2. The circuit is in charge of making the necessary calculations of echo to determine the distance. This device has an input signal (***TRIGGER***) and an output signal **(ECHO**). The Trigger sends out an ultrasound pulse that propagates at the speed of sound, that is 343m /s. Upon finding a target to work on, the pulse is reflected back and echoed back to the sensor. For this reason the sensor is said to have the same principle as echolocation (echo) [7].

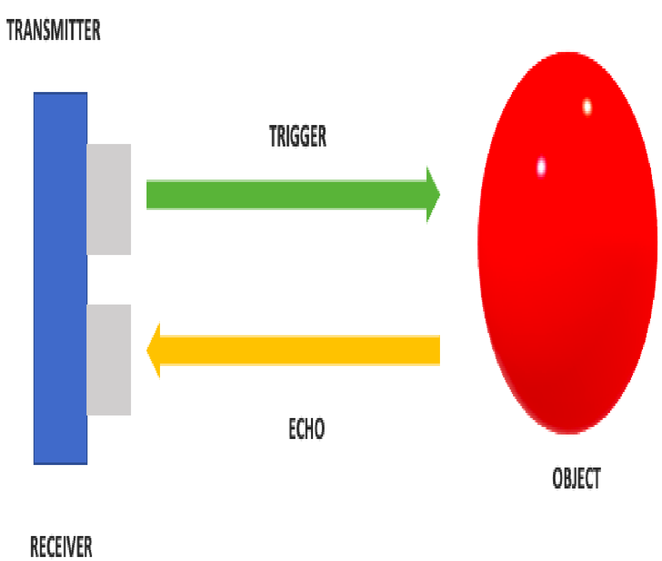

Fig. 2: Ultrasonic Sensor Operation Diagram

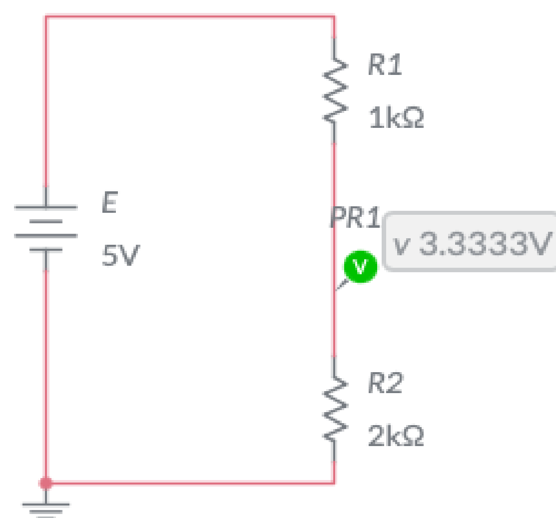

Fig. 3: Voltage Divider Output 3.3V for GPIOs

To measure the distance, which is considered digital but it is an advanced sensor. It uses the 5 Volts power pins and ground. This energy is received through the Raspberry Pi, which provides 5 Volts to make the sensor work. TRIGGER and ECHO pins are connected to the General Purpose Input/Output (GPIO) pins of the Raspberry Pi. However, all GPIOs work at 3.3V - Then it is necessary to reduce and regulate the voltage by applying a voltage divider composed of 2 resistors. In this case a 1kΩ resistor and another 2kΩ resistor were used as shown in Fig. 3. The output voltage required is 3.3Volts as shown in equation (1).

The distance of an assigned object is determined taking into account the speed of sound which is 0.034 cm/us and the calculated time. The time is calculated by the devices, but we need to insert the speed of sound in seconds (34300cm/s) in the python code to calculate the distance as shown in equation (2).

For the speaker or Voice alerts to be configured we need to download and install text to speech in the Raspberry Pi OS terminal [9], as shown in the Fig.4.

```
pip install pyttsx3
sudo apt-get install espeak
```

Fig. 4: Installation of Raspberry Pi Text to Speech

The coding part to convert the text to speech is show below:

```
eng = pyttsx3.init()
if distance <= 10:
      eng.say("Object Ahead")
      eng.runAndWait()
      time.sleep(2)
```

Schematic Connection system is shown in Fig. 5:

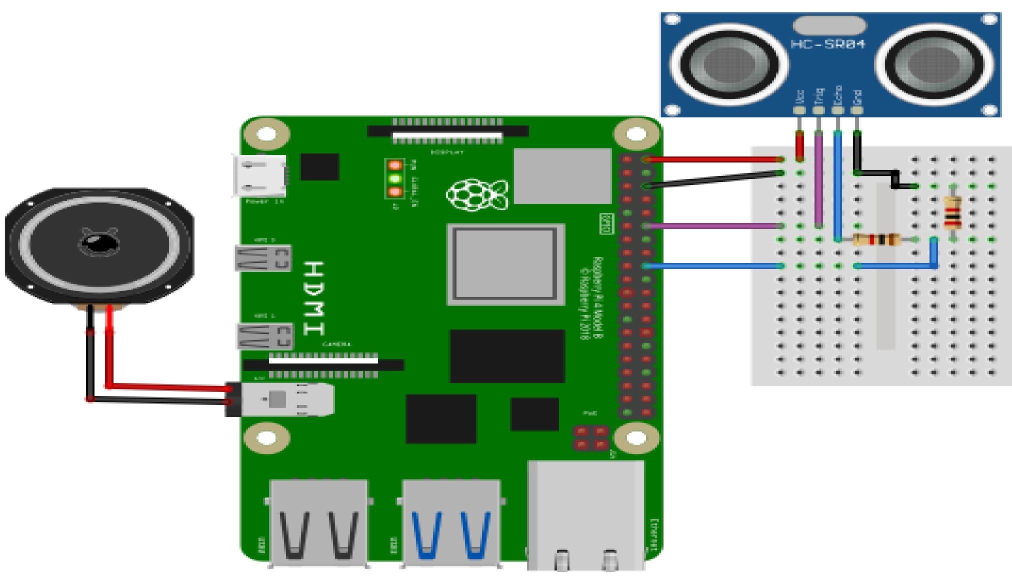

Fig. 5: Ultrasonic Sensor and Speaker Connection System

2.3. Real-Time Object Detection with Raspberry Pi Camera

For object detection we have used a Raspberry Pi 4 board with python 3.x and a few libraries in order to detect an object in real time as shown in Fig. 6. The flow of how the object detection should work is shown in Fig. 7. We also have made use of the Raspbian Operating System with libraries such as *Os*, *OpenCV*, *argparse, numpy*, *sys, time*, *threading*, and *importlib.util*.

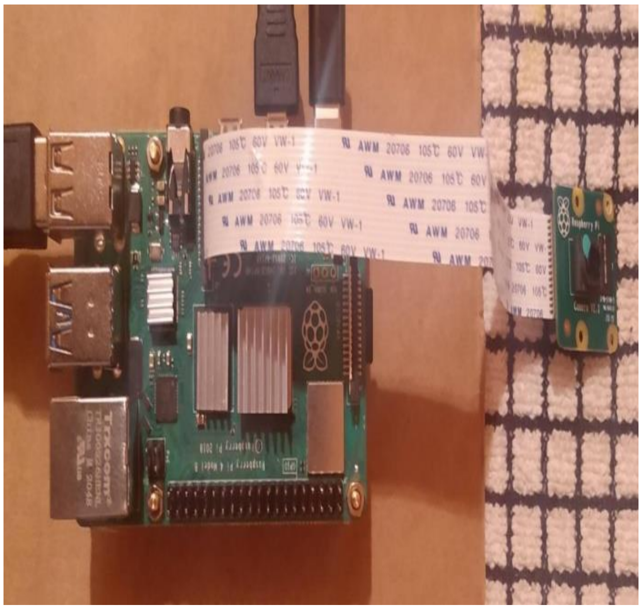

Fig. 6 Circuit for object detection

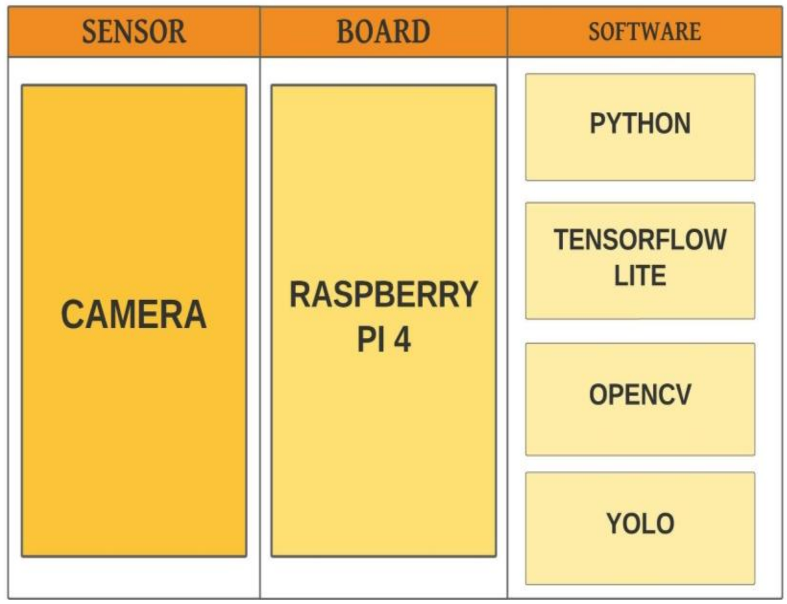

Fig. 7 Chart of how the object detection will work. It starts with the camera, flows to the Raspberry Pi4, then to python

OpenCV is an open-source library for computer vision that enables us to see objects that are nearby while tensorFlow lite detects the object Fig. 8 [13]. *Os* is a library that help us interact with the operating system or simply put anything with changing directories [14]. The *argparse* helps us write user-friendly command prompt interfaces [15]. *Numpy*, provides us comprehensive mathematical functions: Fourier Transform, Linear Algebra routines to expedite the manipulation of arrays and more [16], [17]. The *sys* library is used to provide access to some variables used or maintained by the interpreter or functions that interact with the interpreter to manipulate different parts of the python runtime environment [18], [19]. The *time* library is used for various time related functions. The *threading* library is used for running multiple I/O tasks simultaneously [20]. Finally, the *importlib.util* provides an implementation of import to load codes in packages and modules [21].

The process of object detection makes extensive use of the *TensorFlow* library. This library is an end-to-end open-source platform for machine learning, it helps users incorporate training models for machine learning applications and a deep neural network for other tasks by providing a great amount of deep learning libraries [10], [11]. *TensorFlow* is mostly used for training the model, then the output data of what makes an object can be used by other sets of tools or algorithms that can work with embedded and IoT devices [22]. Our effort was focused on using the YOLO algorithm; however, for convenience we made use of the *TensorFlow Lite*. The YOLO library is an algorithm that uses neural networks for real time object detection – The group of programs are best suited for detecting an object, due that detection of an object occurs in real time [12]. *TensorFlow Lite* uses already trained models and works with embedded systems or mobile devices, similar to YOLO.

TensorFlow was used to train the models we want our camera to see. Thereafter, *TensorFlow Lite* was applied to the already trained models to detect the object. The program is executed in the terminal with the *openCV* turning the camera on. This action happens when the raspberry processes the code and communicates with the camera through the CSI interface. When the camera is turned on it receives data or images. These images, represented as data, are then sent back to Raspberry Pi, the Python interrupts it and uses the *tensorFlow lite* to figure out what the camera is seeing. When *tensorFlow lite* acertains of what is seeing, *openCV* draws a rectangle around the object and adds a label. All this happens under the frame rate of 30fps. This event happens continuously, because identifying the object part of the code is all under the while loop control. The while loop is broken only when someone interrupts, such as pressing “CTRL + C” otherwise the code keeps going.

Fig. 8: Image shows a person being detected, high confidence when it is a person, a rectangle is displayed around him.

2.4. Equations

The equations show how to obtain the 3.3V for the GPIOs through Voltage Divider, as well as the calculations of how to obtain the distance of the ultrasonic sensor and the objects:

$$V_{out} = V \quad \times \frac{R_2}{R_1 + R_2} = 5V \times \frac{2k\Omega}{1k\Omega + 2k\Omega} = 3.33V \tag{1}$$

$$\frac{Distance}{Time/2} = 34300\, cm/s\, ; Distance = Time \times 17150\, cm/s \tag{2}$$

3. White Cane Implementation

The location of the Raspberry Pi camera and the ultrasonic sensor on the walking stick are the key points to avoid accidents when using it. Fig.9 shows the place where these components are attached.

Fig. 8: Camera and Sensor Attached to White Cane.

4. Conclusion

Improvements on technology have enabled us to miniaturise computers. This trend has been very helpful for improving outdated tools; in our case we made it to a White Cane. A Raspberry Pi equipped with a few appropriate peripherals helped us to improve the functionality of the White Cane making it a viable option for people with visual impairments to use. The Ultrasonic sensor paired with a speaker extends the range of detection for the White Cane allowing users to detect obstructions that could injure a person's top part of the body namely the head. The Raspberry Pi camera using Machine Learning AI was able to detect objects and then inform the person of what is ahead, this helped the user make decisions on how to proceed. Our system was implemented around the White Cane in order to keep them from having to learn a new method of getting around and just building upon techniques already known. Our solution with the help of machine learning can make blind people more independent and less reliant on other people's help to do everyday tasks.

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