Multi-Sensor Obstacle Detection System in Smart Cane Design for The Visually Challenged

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Abstract— A Smart canes helps in the secure navigation of visually challenged individuals by sensing and alerting obstacles beyond the physical extent of the cane. This project aims to enhance navigation safety for visually challenged individuals by developing a streamlined smart cane. Integrating ultrasonic and pi camera for obstacle detection and audio alerts, the design ensures a comprehensive awareness of the surroundings. Sensors are strategically positioned to cover left, right, and vertical directions. Despite noise challenges from low-cost sensors and user hand movements, this focuses on refining obstacle detection using a pi camera, which is used for image recognition. Furthermore, the smart cane incorporates a feature allowing visually impaired users to engage in text recognition using the python-tesseract algorithm and includes an emergency calling system for added security. This innovative solution holds promise in significantly improving the safety and independence of visually impaired individuals during navigation.

***Index Terms*— Smart cane, Ultrasonic, Pi camera, Object detection, Text recognition, Python-tesseract, Emergency contact.**

1. Introduction

The development of a multi-purpose sensing system represents a new evolution in assistive technology, specifically designed to improve the mobility and safety of visually impaired people. This smart cane design uses cutting-edge technology to deliver significant improvements in solving the unique challenges faced by the visually impaired. The smart cane is equipped with various sensors that detect more problems than just helping with movement.

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At the heart of the system are ultrasonic sensors that work together to create a dynamic, real-time map of the user's location. Sensors constantly scan the environment, providing constant information to detect problems and changes in the ground. This innovation has set a new standard for service technology as our world recognizes the importance of meeting diverse needs. It ensures that visually impaired people not only have equality but are also equipped with the tools to participate and contribute to society. This technology is essentially not just a tool but also a valuable source of time and freedom. It allows users to explore the world with unprecedented freedom, interact with their environment on their own terms, and control their own destiny. Sensor obstacle detection systems represent the pinnacle of integrated, user-centered design. By seamlessly integrating technology into daily life, it brings a new sense of control and freedom to those limited by lack of vision.

2. Comparison With Other Blind Stick

White canes have become an iconic symbol for individuals with visual impairments for supporting them in mobility and navigation. Their short response range limits obstacle detection below knee level. To address these challenges, electronic travel aids (ETA) emerged in the 1970s. Sensor technology is one of the most important factors that can enhance the performance of an ETA. Smart cane device is a type of ETA which is usually designed to fit on top of the white cane for obstacle detection above and below knee level. There are three ultrasonic sensors and the system also integrates a raspberry pi, pi camera and a bluetooth module for wireless audio feedback. Smart canes and white canes are both important mobility aids for individuals with visual impairments, yet they diverge in functionality, technology integration, and user experience. Traditional blind sticks rely on a simple but effective design, utilizing tactile feedback to detect obstacles and changes in terrain. The User moves the cane back and forth, interpreting the vibrations and resistance to navigate safely. While this method has been reliable for decades, it provides limited assistance beyond basic obstacle detection. In contrast, smart canes represent a leap forward in assistive technology by integrating advanced sensors such as ultrasonic sensors, pi cameras, etc. These sensors provide accurate feedback about the environment, including the distance and direction of obstacles. Additionally, smart canes often incorporate various feedback mechanisms such as audible alerts and haptic feedback to increase the user's situational awareness. Some models are even integrated with GPS navigation systems to provide turn-by-turn directions and location awareness, further empowering individuals with visual impairments to navigate independently. However, these advancements have made the smart canes more expensive and may need a learning curve for users to adapt to the new technology. Furthermore, accessibility of smart canes may be limited due to cost and availability, especially in regions with limited resources. Ultimately, the choice between a smart cane and a traditional smart stick depends on the user's preferences, needs, and access to resources.

3. Basic Working Principle

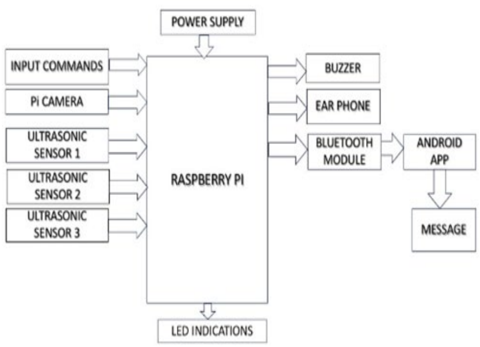

Fig.1. Block diagram of smart cane

Smart cane configuration is a simple design with integration of raspberry pi, ultrasonic sensors and pi camera for object detection, and audio techniques for the feedbacks has been implemented for the prototype in this work. The sensors are positioned in such a way that the sensing range of the ultrasonic sensors is from the ground level to the head level. Therefore, it is to design and develop a walking stick with the features such as real time object recognition, text recognition, voice guidance, navigation etc. and cost effective to all the people who are in need for help. The focus of this work is on improvement of the object detection, allow visually impaired to identify text, and to provide emergency support system in a smart cane. The system uses the YOLO algorithm to detect objects within the camera's field of view. It also uses text-to-speech technology to verbally communicate any written or printed document and additional security system during emergency.

A. Object Detection

The smart stick adopts YOLO (You Only Look Once) version. 3 Object detection algorithm and raspberry pi. Object detection is a computer vision system that allows system to identify and find objects in images or videos. YOLO is a real-time object detector that can capture objects in photos and videos. The YOLO algorithm uses a single neural network to process the entire image, allowing objects to be detected very quickly [7]. Raspberry pi is a low-cost, credit card-sized computer. It consists of a raspberry pi and a camera module connected to the Pi. To identify objects, smart devices use object detection algorithms. YOLO is designed to provide end-to-end training and speed while maintaining average accuracy. It processes the images captured by the camera and identifies objects in the images. Each grid foresees a certain number of checkboxes (sometimes called anchor boxes) around items that score highly in the previous category. Each bounding box has its own confidence score, which indicates how accurate its prediction is. Only one object is accepted per limited box.

Containers are created by finding the shapes and sizes of the boxes by separating them from the ground truth of the dimensions in the original document.

B. Optical Character Recognition

OCR is one of the input devices that can be used to read printed text. The OCR scans the texts through light and character by character, converts it into a machine-readable code and saves it on a system memory or convert it into a document. It is very useful and popular in wide range of applications. The efficiency of OCR depends on text preprocessing and segmentation algorithms. Sometimes, retrieving text from an image becomes difficult because it may have different size and style or the background of the image could be complex. Smart cane uses python-tesseract algorithm for optical character recognition which allows visually blind users to analyze and read printed or written text or documents. Tesseract is an open-source optical character recognition (OCR) engine that can be finely tuned up using many languages even multilingual text as well as vertical scripts among others. It has been developed as a camera-based assistive reading system helping blind individuals to read out labels on objects and documents within their normal daily activities.

C. Emergency System

In some cases, visually impaired people experience many problems in unknown places or have some health problems and want to contact their parents or friends immediately.

Android emergency application is used in this system. The app is built using Android studio and Google Map API which provides the user's location so others can see the user. APP shows the latitude and longitude of the place written on the map. After many tests, it has been determined that this application is beneficial for blind and low vision people. Press the home button to send the emergency message to the emergency contact registered in the app. The article includes the location according to latitude and longitude, as well as a link to Google Maps. Therefore, when this link is clicked, the user is directed to Google Maps, which shows the exact location.

4. Hardware Setup

The system consists of 3 ultrasonic sensors, push button, pi camera, raspberry pi, blue-tooth module, and audio outputs. There are 3 input command buttons provided in the stick, as object switch, as OCR switch and as emergency switch. When object is detected by ultrasonic sensors, gives an alert to the user via buzzer. The object detection is done by YOLO algorithm, OCR is performed using python-tesseract algorithm and for emergency situation, an alert is given through message to the emergency contact of the blind. Since the size, cost, and appropriateness of the materials are well considered, the PVC is finally decided to be used. Holes in different sizes were drilled to house the sensors, power buttons and buzzer as the siren system.

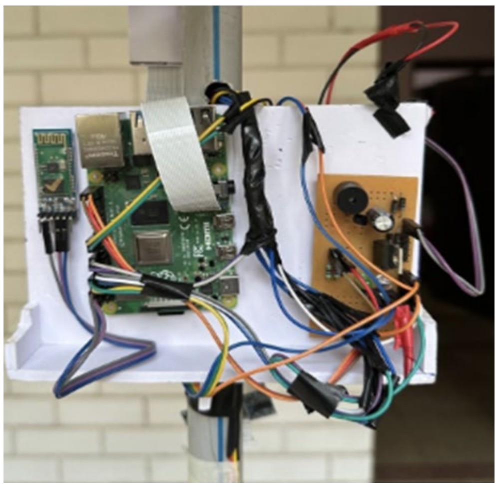

Fig.3. Raspberry-pi connection

Firstly, the PCB circuit was designed on the diptrace software for easy modification task. Once the circuit is finalized, printed circuit board (PCB) was fabricated. The important element when designing the PCB is the size of the PCB; which is long rather than wide. It is also to make sure that the design of Smart Cane is as small as possible. The VCC of 5V of all the modules, and all the ground of the models will be connected to the GND on the raspberry pi 4 board.

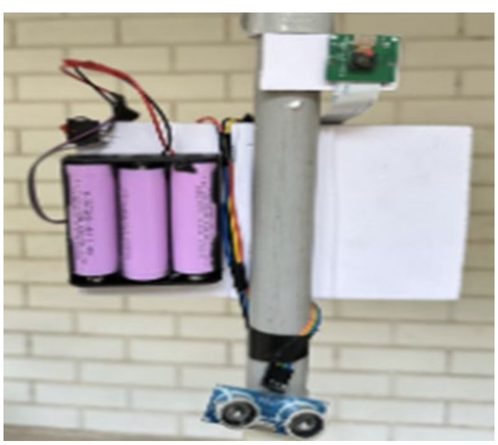

Fig.4. Pi-camera, Battery, Ultrasonic sensor

A raspberry pi 4 is a CPU that does not and hit as any in-built analog to digital converter, which only takes the digital form of data. Using the VNC viewer, the code is implemented in raspberry pi 4, begins to display. The ultrasonic sensors, camera, buzzer, audio outputs, and blue-tooth module are connected directly to the raspberry pi 4. The VCC hit as 5V supply, and GND is linked to the GND on the pi. The interconnecting ultrasonic sensors of the VCC of 5V, trigger pins 1, 2 ,3 is connected to GPIO 23, 25, 18 respectively, Echo pins is connected to GPIO 24, 8, 15 respectively and GND is connected to GND of the raspberry pi pins. Buzzer pins are connected to the GND and GPIO 21. Help button, object button, OCR button is connected to GPIO 17, 27, 22 respectively.

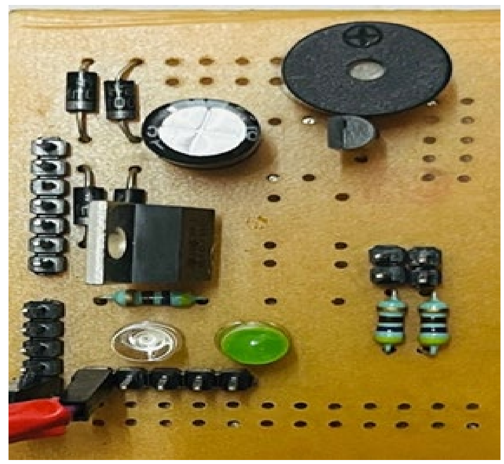

Fig.5. PCB Circuit

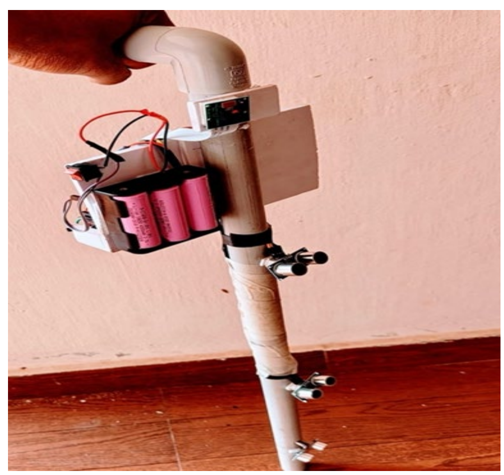

Fig.6. Smart Cane

5. Results And Discussion

A. Hardware Result for Object Detection

The identification of obstacles is done by UV sensor [2]. The UV sensor consists of four pins - trigger (TX), echo (RX), vcc and gnd. When the supply is given to the UV, the transmitter constantly produces sound waves and the receiver receives echo pulses when there is a problem within 2 meters. According to the distance of wave propagation, the calculation formula of distance is: Distance = (high level time * ultrasonic spreading velocity in air)/2 [2]. Obstacles is detected and alerts the visually impaired people When the push button is ON, then the pi cam functions, otherwise it remains in the idle state. The image captured by pi cam is then processed by YOLO. The processed image is classified into particular class of predefined data, here used COCO file, which is having features of about 70 things. Thus, the object in the image is detected according to their features related to the predefined dataset. Fig.7a and fig.7b. shows the result of image detected as keyboard according to the predefined class.

Fig.7a. Keyboard

Fig.7b. Object is Detected as Keyboard

B. *Hardware Result for Optical Character Recognition*

Optical character recognition is also known as text recognition method. The main pro- cess of OCR is to identify scanned documents and use them further for data processing. OCR systems [2] are a combination of hardware and software. An optical printer or some special circuitry is used to scan printed documents and software analyzes the captured images for further processing. If the button is ON, the pi camera is on, otherwise the camera is off. Pi camera captures text from images and processes it using OCR technology [8]. Alphanumeric characters in the image are recognized and converted into speech. Voice messages are delivered to visually impaired people through headphones. Fig.8. shows the result of Optical character recognition using pytesseract algorithm.

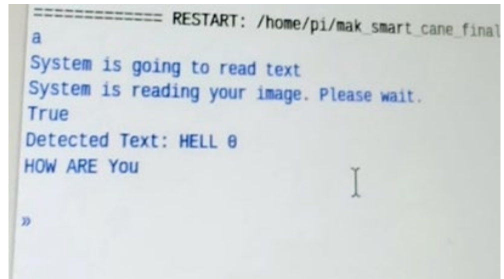

Fig.8. Result of OCR

C. *App Development for Emergency Contact System*

Bluetooth module is connected to raspberry pi. An app is developed using android studio which automatically send message to the emergency contact provided in it. when the push button is ON, it triggers the bluetooth module to be turned ON and is connected with the blind person’s phone [9]. A message is sent to emergency contact of the blind through the app developed. The app send message along with the google map location. Thus, it helps others to find the location of visually impaired during an emergency [9]. Fig.9a. and fig.9b. shows the emergency message and location of the blind.

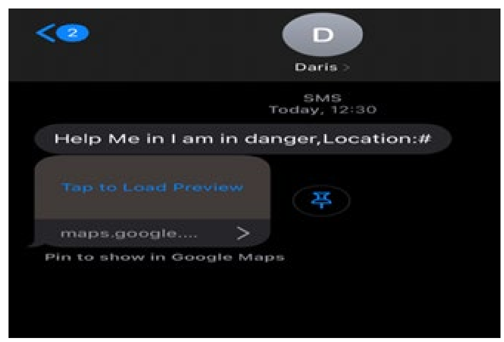

Fig.9a. Notification Message

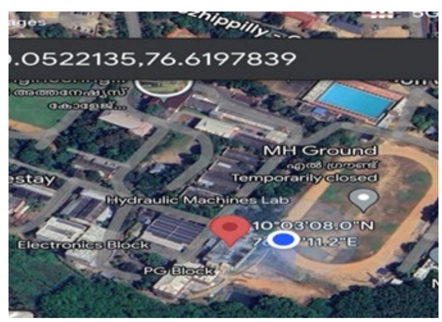

Fig.9b. Location Information

6. Conclusion

The integration of ultrasonic sensors, pi camera, and raspberry pi in a smart cane marks a substantial leap in assistive technology for individuals with visual impairments. This combination of advanced sensors and raspberry pi enhances the device’s capabilities, making it a reliable and intelligent mobility aid [1]. The blind stick can aid the visually impaired user by helping them to navigate by detecting types of objects by using machine learning and getting processed output in the form of audio output. It also offers a camera-based assisted reading system to assist blind people in reading text labels and written documents from everyday things and it also incorporates an emergency contact system for added security. The system is lightweight and portable and will provide them with a sense of security and freedom, allowing them to enjoy an orderly life.

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