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Blind Navigation Support System using Raspberry Pi & YOLO

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Abstract - Visually impaired encounter several challenges in their daily lives to impact their independence, safety, and overall quality of life. Visual impairment can be caused by a range of conditions, such as age-related macular degeneration, glaucoma, cataracts, or genetic disorders. A blind navigation system with object detection is designed to assist visually impaired individuals in navigating their environment safely and independently. This system uses a combination of TensorFlow (YOLO), OpenCV, Noir camera, ultrasonic sensor, and Raspberry Pi to achieve real-time object detection and provide audio feedback to the user about the type of detected objects. The use of TensorFlow (YOLO), OpenCV, Noir Camera, Ultrasonic sensors, and Raspberry Pi, in particular, has made it possible to develop a highly effective and accurate system for visually impaired individuals by providing real-time feedback about the user's environment, this system can help improve the user's confidence and independence while navigating through their environment, and can greatly improve their quality of life.

Keywords – Visually Impaired, Blind, Raspberry pi 4, Object Detection, Ultrasonic Sensor.

I. INTRODUCTION

Blind Navigation Support System is a technology that helps visually impaired individuals in navigating their surroundings. The goal of this system is to enhance the independence and safety of blind people by providing them with accurate and real-time information about their surroundings. There are various ways in which a Blind Navigation Support System can be implemented. In some methods use of sensors, such as ultrasound or infrared, and audio output. For example, an ultrasound system may use high-frequency sound waves to detect obstacles and provide speech output to the visually impaired person through speakers. Similarly, an infrared system may use sensors to detect objects and provide information about their distance and location. One of the most critical components of a Blind Navigation Support System is the audio output. This is because the system must provide articulate information to the user in a way that is not too complex to decipher. Another critical aspect of a Blind Navigation Support System is the ease of use. The system should be intuitive and straightforward so that users can quickly understand how to operate it. This is especially required for elderly users with limited technology experience. One of the challenges of implementing a Blind Navigation Support System is ensuring that it is accurate and reliable. For example, the system should be able to detect obstacles even in challenging environments, such as crowded city streets. Additionally, the system should provide accurate information about the location of objects, such as stairs or curbs. To overcome these challenges, many Blind Navigation Support Systems incorporate machine learning algorithms. These algorithms can learn from the user's interactions with the system, adapting to their preferences and habits over time. For example, the system may learn to provide more detailed information about objects that the user frequently interacts with, such as a favourite coffee shop. Blind Navigation Support Systems also offer the potential to enhance the overall quality of life for blind individuals. By, providing them with concise and trustable information about their environment, these systems can help to reduce stress and increase confidence. Additionally, Blind Navigation Support Systems can also help visually impaired individuals to access new opportunities, such as education or employment, that may have been previously unavailable to them. Blind Navigation Support Systems represent a significant step forward in the development of technology for visually impaired individuals. By providing accurate and reliable information about their surroundings, these systems can help to enhance the independence and safety of blind people. Additionally, Blind Navigation Support Systems also offer the potential to improve the overall standard of living for visually impaired individuals, providing them with new opportunities and helping to reduce stress and increase confidence. The most pivotal skill needed for these unfortunate people to live everyday life is navigation. In this design we try to give nautical aid with the following

1. Raspberry pi is used to implement object detection using OpenCV, Tensorflow (YOLO algorithm)
2. Three ultrasonic sensors are deployed to get a 180-degree Panoramic field.
3. Buzzer whose buzzing intensifies with the distance from Objects.

4. 'pyttsx3' library is used for text to speech conversion.

II. LITERATURE SURVEY

Woojin Jung," Integrated Navigation System for Internal Service Robots in Large- Scale surroundings". Woojin Chung developed a federated navigation system for internal service robots that can operate in big-scale areas, such as airports and shopping centres. The system uses a combination of sensor data and map information to create a precise and most recent representation of the robot's environment, allowing it to navigate autonomously and avoid obstacles. The system was tested in various environments, and the outcome showed that the robot was easily able to navigate successfully and efficiently, demonstrating the potential for use in real-world applications [1].

Denis Tudor, Lidia Dobrescu, Drago Dobrescu, "Ultrasonic Electronic System for Blind People Navigation" Denis Tudor, Lidia Dobrescu, and Drago Dobrescu developed an ultrasonic electronic system to assist visually impaired in navigation. The system has ultrasonic sensors to detect objects in the vicinity of the user and provide feedback to the user using an auditory interface, including a speaker or headphones. The system had many test cases in a real-world environment with blind users, and the results showed that it was effective in assisting with navigation and increasing the user's sense of confidence and independence [2].

Kanchan M. Varpe, M.P. Wankhade," Visually Impaired Assistive System" Kanchan M. Varpe and M.P. Wankhade developed a blind assistive system to help individuals with visual impairments navigate their surroundings. The system uses a combination of sensors such as ultrasonic and infrared to detect objects and provide feedback to the visually impaired through a vibrating belt. The system was tested with visually impaired users, and the results showed that it was effective in helping them navigate their surroundings safely and with increased confidence [3].

A. Aladrén, G. López-Nicolás, Luis Puig, and Josechu J. Guerrero "Navigation Assistance for the Visually Impaired Using RGB-D Sensor with Range Expansion" A. Aladrén, G. López-Nicolás, Luis Puig, and Josechu J. Guerrero developed a navigation guidance system for the blind using an RGB-D sensor with expansion in range. The system had a combination of RGB and depth data to detect obstacles and provide feedback to the user through a haptic interface, such as a vibrating waistband or gloves. The system had test cases in a real-world environment with visually impaired users, and the results showed that it was effective in assisting with navigation and providing the users with a better sense of spatial awareness [4].

B.S. Tjan, P.J. Beckmann, R. Roy, N. Giudice, and G.E. Legge, "Digital Sign System for Indoor Wayfinding for the Visually Impaired". B.S. Tjan, P.J. Beckmann, R. Roy, N. Giudice, and G.E. Legge developed a digital sign system for visually impaired to find ways in internal or indoor environments. The system uses a network of digital signs with voice and text messages to provide directions and other information to the user. The system was tested in a real-world environment with visually impaired users, and the results showed that it was effective in assisting with indoor wayfinding and providing users with a greater sense of independence and autonomy [5].

To feel secure while moving indoors or outdoors, individuals with visual impairments require some kind of assistance. This assistance may come in various forms, such as the Intelligent Walking Stick, Distance Notification System, Wayfinder, Ultrasound System, Novell Indoor System, and others. Visually impaired individuals have used these systems, which use various techniques, including electronic systems that rely on ATmega328P microcontrollers, remote processing systems that use computer vision algorithms for analysis, guided technology devices like Electronic Canes and Eye Sticks, and tactile signals that provide information instead of the acoustic signals from traditional white canes or Hoover sticks.

III. METHODOLOGY

Machine Learning, Deep Learning and Artificial Intelligence are technologies that has being increasingly used in the development of blind navigation systems. These technologies allow these systems to improve their accuracy, reliability, and overall performance.

Artificial Intelligence is the capacity of machines to perform jobs that typically require human thought process, such as recognizing different sets of continuation, making predictions, and making right decisions on the basis of all the observation. Machine Learning comes under the wider strata of Artificial Intelligence that focuses on the algorithm development that enable machines to learn from their observation and upgrade their performance constantly. Deep Learning, on the other hand, is a type of Machine Learning that leverages artificial neural networks to model complicated patterns in large datasets.

In the context of blind navigation systems, AI and Machine Learning are used to develop algorithms that can detect obstacles and provide accurate information to the user. For example, Machine Learning algorithms can be trained on large datasets of sensor data, such as ultrasound or infrared readings, to detect objects in the environment and give feedback to the user. Additionally, AI and Machine Learning can be used to develop algorithms that can learn from the user's interactions with the system, adapting to their preferences and habits over time.

Deep Learning is also playing a pivotal role in the development of blind navigation systems. Deep Learning algorithms can be used to process images and other sensory data to provide a more detailed representation of the user's environment. These algorithms can be trained on large datasets of images and other sensory data to detect obstacles with a high degree of accuracy, even in complex and dynamic environments [6].

In conclusion, Artificial Intelligence, Machine Learning, and Deep Learning are the main technologies that has being used in the development of blind navigation systems. These technologies allow these systems to improve their accuracy, reliability, and overall performance, making them more effective and user-friendly. By leveraging the capabilities of AI, ML, and DL, blind navigation systems are being used to amplify the independence and safety of visually impaired individuals, providing them with the information they need to navigate their surroundings with confidence.

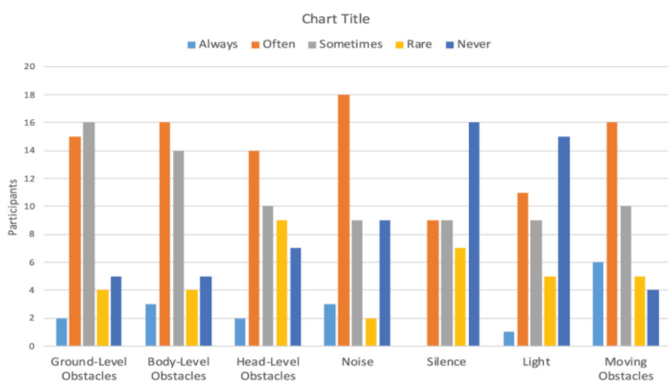


Fig 3.1 Obstacles Classification

IV. . PROPOSED SYSTEM

DISADVANTAGES OF THE EXISTING SYSTEM*:* The existing systems uses only 1 ultrasonic sensor which can sense obstacles only in 1 direction. The object detection is also unable to capture image clearly in dark or during night time.

PROPOSED SYSTEM: This system will be having 3 ultrasonic sensors which will offer a panoramic field. It will also be equipped with a flashlight which turns on during object detection to give a much clearer image. We are also aiming for an higher speed with yolo algorithm (45 frames per second)

ADVANTAGES: Blind Navigation support system will help those who are visually impaired to go by their daily tasks without external helps or guide dogs. This will help those unfortunate people to have a modicum of normalcy and will also help them lead an independent life

A. HARDWARE AND SOFTWARE R EQUIREMENTS:

The completion of the analysis task marks the production of the software requirements specification. At this stage, the software's designated function and performance within the system engineering framework undergo a thorough refinement process. This involves creating a comprehensive information description that represents the system's behaviour, outlining its performance requirements and design limitations, and identifying suitable validation criteria.

- A Raspberry Pi
- Monitor (with micro-HDMI adaptor)
- A USB keyboard and mouse
- A power supply
- Headphones or speakers (optional)
- An ethernet cable (optional)
- Pi camera
- Ultrasonic Sensor
- Operating system: Linux(preferable) or windows 10
- Raspberry Pi OS, installed using the Raspberry Pi Imager

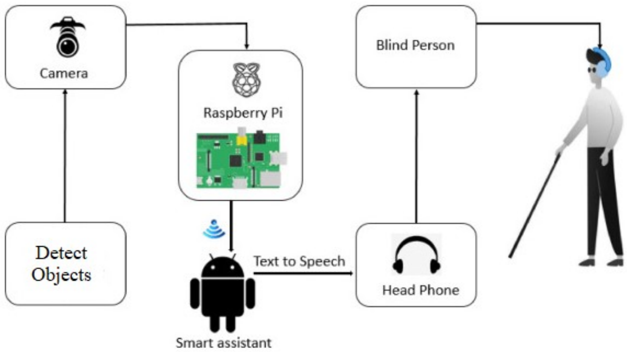
Raspberry Pi OS is a free and open-source operating system designed to run on Raspberry Pi single-board computers. It is based on the Debian Linux distribution and includes a graphical user interface, software development tools, and a suite of pre-installed applications. There are various reasons to choose raspberry pi over its competitors- cost effectiveness, low power consumption, small size factor, high degree of customization as well as having a huge community for support and troubleshoots.

Ultrasonic sensors emit high-frequency sound waves and detect the echoes that bounce back from objects in the environment. This can be used for object detection in close-range scenarios, such as parking sensors in vehicles.

Computer vision techniques involve analysing digital images or videos to extract information about the objects within them. This can be done using algorithms such as edge detection, feature extraction, or template matching.

Overall, object detection techniques vary depending on the context, the technology being used, and the desired level of accuracy and precision.

B. ARCHITECTURE DIAGRAM:



Object Detection Workflow

Fig. 4.1: Architecture Diagram

The Pi camera captures live video footage of the surroundings.

The OpenCV library is used to pre-process the video data and extract relevant features.

The YOLO algorithm is applied to the preprocessed video data for object detection.

The TensorFlow library is used to process the output of the YOLO algorithm and perform further image recognition tasks.

The ultrasonic sensor is used to detect obstacles in close proximity to the user.

The Raspberry Pi combines the output from the ultrasonic sensor with the object detection data to determine the location of objects in the user's environment.The system provides audio feedback to the user based on the detected objects, enabling them to navigate their surroundings more effectively.

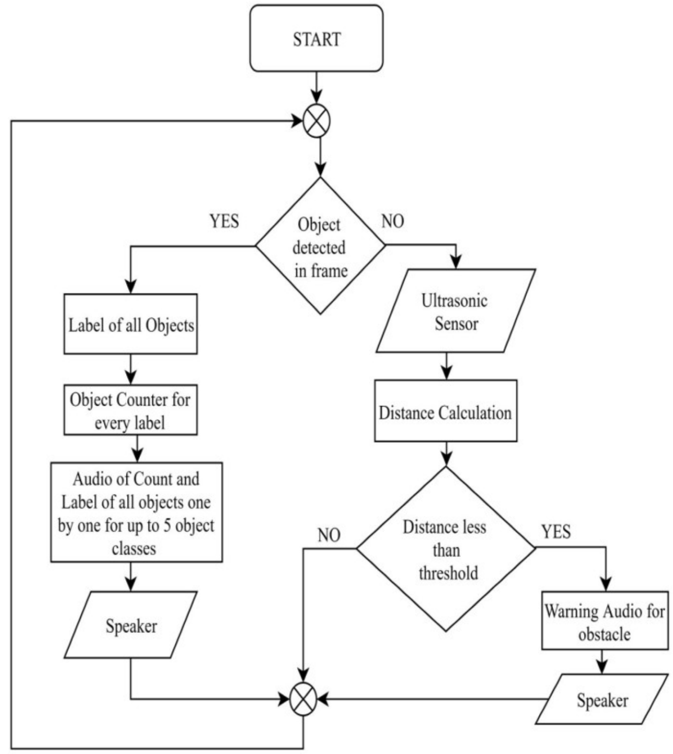


Fig 4.2 Flow Diagram

C. DATASET:

MS COCO (Microsoft Common Objects in Context) is a large-scale image recognition dataset for training and evaluating computer vision algorithms. It contains 330,000 images and 2.5 million object instances, labelled with 80 common object categories, such as people, animals, vehicles, and furniture. The images in MS COCO come from a different number of sources, including natural images, cartoons, and abstract scenes, and cover a wide range of object scales, orientations, and poses. MS COCO is widely used in researches pertaining to computer vision, and has helped to advance the development of deep learning algorithms for image recognition and object detection. The dataset is freely available for research purposes, making it a valuable resource for the AI community.

D. PYTTSX3 LIBRARY:

Pyttsx3 is a Python library that provides cross-platform text-to-speech (TTS) functionality. It enables developers to add natural-sounding voice output to their applications by converting written text to speech in real-time. The library supports a range of TTS engines, including the native Windows and Mac OS X voices, as well as third-party options such as eSpeak and Festival. Pyttsx3 is easy to use and includes a simple API for controlling speech rate, volume, and voice selection. It is open-source software and is available under the MIT license, making it free to use and modify for both commercial and non-commercial projects.

When implemented on a Raspberry Pi for object detection, YOLO, ultrasonic sensors, pyttsx3, OpenCV, and YOLO algorithm can play the following roles:

YOLO Algorithm: YOLO is an object detection algorithm that can detect objects in real-time. When implemented on a Raspberry Pi, YOLO can be used to perform object detection on live video streams or images. The YOLO algorithm is computationally intensive, so optimizing it for the Raspberry Pi can be a challenge.

Additionally, there are several ways to improve the accuracy of YOLO object detection model:

1. Increase the training dataset: A larger dataset can help the model learn to recognize more objects, variations, and backgrounds. Ensure that the dataset is diverse and includes a variety of angles, lighting conditions, object sizes, and shapes.
2. Fine-tune the pre-trained model: YOLO comes pre-trained on COCO dataset, which is a large dataset that includes various objects. Fine-tuning the model on your specific dataset can help the model to learn more about the specific objects in your images.
3. Adjust the anchor boxes: Anchor boxes are predefined shapes that are used to identify the location of objects in an image. Adjusting the anchor boxes to better match the size and aspect ratio of objects in your dataset can improve accuracy.
4. Increase the number of training iterations: Increasing the number of iterations can help the model to learn more about the objects in your dataset and improve accuracy.
5. Use data augmentation: Data augmentation techniques such as rotation, flipping, and scaling can help to increase the diversity of the training data and improve the model's ability to recognize objects.
6. Use a larger network architecture: Using a larger network architecture, such as YOLOv3 or YOLOv4, can help the model to learn more complex features and improve accuracy.

Another advantage of using YOLO is that different combination of techniques such as anchor boxes, NMS, training on a large dataset, fine-tuning the model, using high-quality images, and regularization techniques, can help YOLO achieve high reliability in object detection.

By combining multiple tricks, PP-YOLO can achieve a better balance between effectiveness (45.2% mAP) and efficiency (72.9 FPS), surpassing the existing state-of-the-art detectors such as EfficientDet and YOLOv4 [7] [8] [9].

According to the study, PP-YOLO has shown to surpass YOLO v4 in terms of mean average precision (mAP) on the COCO dataset, achieving a score of 45.2% compared to YOLO v4's 43.5%. Additionally, when tested on a V100 with batch size = 1, PP-YOLO demonstrated an inference speed of 72.9 FPS, which is faster than YOLO v4's 65 FPS. The researchers behind PP-YOLO suggest that the superior optimization of tensorRT on ResNet model in comparison to Darknet is the main factor contributing to this performance enhancement.

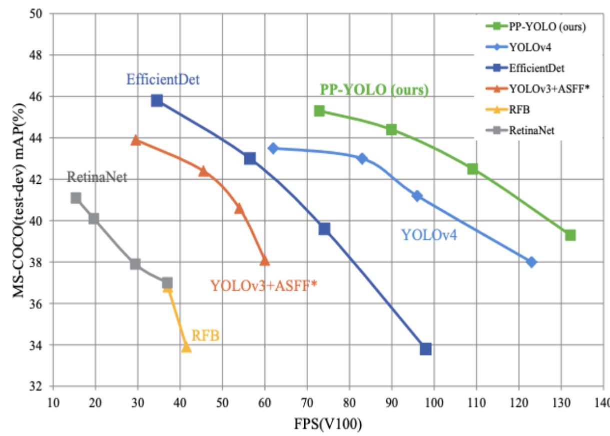


Fig 4.3 YOLO Algorithm Accuracy

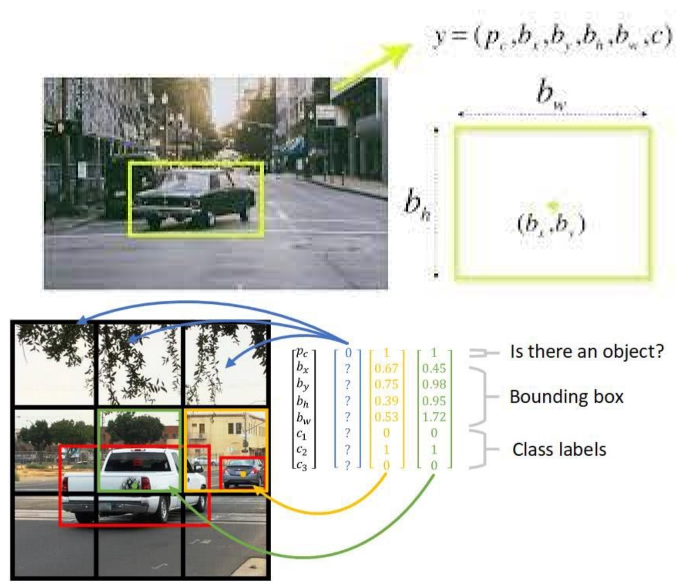


Fig 4.4 Bounding Boxes

OpenCV: OpenCV is a computer vision library that can be used for tasks such as image processing, video capture, and object detection. When implemented on a Raspberry Pi, OpenCV can be used for tasks such as pre-processing input images, resizing images to a suitable size for the YOLO model, and displaying output results.

TensorFlow: TensorFlow is a popular deep learning framework has been used for an extensive range of worked, including training and deploying neural networks. When implemented on a Raspberry Pi, TensorFlow can be used for tasks such as training YOLO models, optimizing YOLO for the Raspberry Pi's hardware, or even for implementing other deep learning models for object detection [10].

Ultrasonic Sensor: The ultrasonic sensor can be used to measure the range between the Raspberry Pi and objects in its vicinity. This can be used to supplement the object detection algorithm and help the Raspberry Pi avoid collisions with nearby objects.

Pyttsx3: Pyttsx3 can be referred as a Python library for conversion from literal to audio output. When implemented on a Raspberry Pi for object detection, pyttsx3 can be used to provide audible alerts or notifications based on the results of the object detection algorithm [11] [12].

V. RESULT AND CONCLUSION

In this study, the system gives great results assuming that the three constraints about the environment are not violated which are

1. Object might have ground like appearance
2. Slopes might result in calculation error in range of the object.
3. System overestimates distance of overhanging objects.

The ultrasonic sensor was able to detect objects in a range of 15cm and buzzing was intensified as the object came closer to the device. The intensification was highest between 10 cm to 0 cm. There was also some miscalculation in the distance of overhanging objects which resulted in no alert being pushed by the buzzer until the diagonal distance came out to be 15cm. We were also able to control and coordinate the buzzing as well as the speech output to avoid overlapping and creating noise.

There are almost 80 datasets available in COCO. Some of which detection time is given below:

1. Person- 0.01s
2. Bicycle- 0.004s
3. Ball- 0.9s
4. Toothbrush- 0.02

VI. FUTURE ENHANCEMENT

The future project pertaining to this paper should aim for a camera that has higher megapixels. Instead of deploying the above project on a stick we can design an application for the ease of the user. We can also aim to deploy additional sensors such as water sensor, gyroscope etc. to give additional features to this hardware. Cost cutting will be a crucial factor of project in future as raspberry pi is a very expensive component thereby deeming it vain for people who are not well financially. We can also employ a translator which may help the blind person to get by easily in non-native destination. A GPS – GSM model can also be deployed for emergency messages and route navigation. There are also several additional features that can be added to this device that enhances its functionality of the system. For example, the system could use GPS to provide location-based information to the user, such as nearby points of interest or public transportation schedules. Additionally, pothole detection using image processing [13] can also be deployed for smoother navigation on roads. This same device can also be used to detect the emotions in the voice of the user and people around them [14] and thereby determining the situation and alerting the right authority. The system could also be integrated with a smartphone app to provide additional functionality and customization options.

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