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Smart Solution for the Visually Impaired

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Abstract: *This research project focuses on the development of a comprehensive assistive system for the visually impaired utilizing a Raspberry Pi 4B 4GB with a camera version 1.3. The system incorporates multiple functionalities including face detection, vehicle detection, text detection, and distance measurement using an ultrasonic sensor. Face detection is achieved through Haar cascade classifiers and a trained YAML file, while YOLOv3 is employed for vehicle detection and recognition of objects like stop signs and mobile devices. Tesseract OCR for text detection, and an ultrasonic sensor for distance measurement. Real-time feedback on detected objects is provided to the user through audio output. This research paper aims to present the design, implementation, and evaluation of this assistive system, highlighting its potential impact on enhancing the independence and safety of visually impaired individuals in navigating their surroundings.*

Key Words: *Smart Device, Visual Impaired, Raspberry Pi, Face Detection, Vehicle Detection, Text Detection, Distance Detection, Assistive System.*

1. INTRODUCTION:

Interacting and feeling environment is difficult for visually disable persons [1]. Such people need to provide new facility The development of assistive technologies for the visuallyimpaired has been a significant focus in recent years, aiming to enhance their independence and safety in navigating their surroundings. This research project explores the integration ofvarious computer vision techniques to create a comprehensive system that can detect and alert the user to different objects and distances in real-time.

According to the WHO (World Health Organization) report, asof 2012 there were 285 million people estimated to be visuallyimpaired worldwide, of which 246 million had low vision and 39 million were blind. The majority of people with poor visionare in the developing world and over the age of 50 [8]. The main challenges faced by blind people come into the contextof managing indoor and outdoor conditions, comprising of numerous barriers and the awareness of the individual in front of them. It is difficult to distinguish person or individuals withonly perceptive and audio knowledge [6].

The system utilizes a Raspberry Pi 4B 4GB with a camera version 1.3 to capture images and videos. It employs Haar cascade classifiers and a trained YAML file for face detection,YOLOv3 for vehicle detection and recognition of objects like stop signs and mobile devices, determining approaching vehicles, Tesseract OCR for text detection, andan ultrasonic sensor for distance measurement.

Visual impairment limits people's independence and ability tonavigate the world, creating serious obstacles in their daily life.These issues have been addressed in large part by assistive technologies, and the development of blind-friendly Smart Device is one potential direction for future research. Withthe intention of improving mobility, accessibility, and all-around quality of life for people who are visually challenged, these devices combine cutting-edge technology. The Smart Device offer a variety of functions aimed at empowering people in their daily lives by leveraging the power of theRaspberry Pi platform, a camera module and ultrasonic sensor

Face Detection: The Smart Device recognize and deliver audio feedback on people near the user's. Users can recognize and connect with others more effectively because to this feature, which encourages improved interaction and conversation.

Text detection: To collect and turn printed or digital text into audible feedback, we combine Optical Character Recognition (OCR) technology. By enabling users to read documents.
Vehicle Detection: When traversing metropolitan surroundings, especially for people who are blind or visually challenged, safety is of the utmost importance. The available technology use algorithms to identify surrounding automobiles, sending out alerts in real time.
Distance detection: It is made possible by the presence of an ultrasonic sensor.

2. PROBLEM STATEMENT :

The primary objective of this research is to design, implement, and evaluate the system's performance in detecting and alerting the user to various objects anddistances. The system aims to provide real-time feedback on detected objects, such as faces, vehicles, text, and distances,to enhance the user's ability to navigate their environment safely and independently.
The visually impaired community faces significant challenges in achieving independence and safe mobility within their surroundings, often relying on external assistance to complete daily tasks. This dependence severely restricts their ability to explore and navigate the world with autonomy. To address this pressing issue, there is an immediate and critical need for the development of advanced, accessible, and adaptable assistive technologies tailored to empower blind individualsin confidently navigating their environments.

The current landscape of assistive technologies falls short ofproviding a comprehensive solution to the visually impaired. Most existing gadgets struggle to offer effective support in dynamic and complex scenarios due to a lack of integration, adaptability, and real-time responsiveness. This deficiency
underscores the urgency of creating an all-encompassing solutionthat harnesses cutting-edge technologies, including computer vision, artificial intelligence, and sensor integration, to significantly enhance the mobility and accessibility of the visually impaired population.

3. LITERATURE SURVEY :

A literature survey on assistive devices for the visuallyimpaired using Raspberry Pi, cameras, and sensors revealsa growing interest in leveraging affordable technology for enhanced accessibility. Vehicle and obstacle detection technologies are vital for guaranteeing safe travel. Additionally, studies underscore the importance of user-centric design and continuous improvement in the development of such devices. The electronic aids for the visually impaired can be categorized into three different subcategories, ETAs, electronic orientation aids, and positional locator devices. ETAs provide object detection, warning, and avoidance for safe navigation [21] – [22]. To detect an obstacle or object and give the user a feedback corresponding to the identified object. The ultrasonicsensors can detect an object within 300 cm by generating a40 kHz signal and receiving reflected echo from the objectin front of it. The distance is calculated based on the pulse count and time-of-flight (TOF). Smart glasses [19], [20] and boots [22], mounted with ultrasonic sensors, have already beenproposed as an aid to the visually impaired. A new approach by Katzschmann etal. [13] uses an array of infrared TOF distance sensors facing in different directions. Villanueva and Farcy [23] combine a white cane with near-IR LED and a photodiodeto emit and detect the IR pulses reflected from obstacles,respectively. Cameras [24], [24] and binocular vision sensors [25] have also been used to capture the visual data for the blind.

Text Detection

The proposed smart system utilizes various methods and algorithms for text detection:
EAST (Efficient and Accurate Scene Text) Detector: The EAST detector is used for text detection in natural scenes. Itis an efficient and accurate method that allows for the detectionof text in images.
MSER (Maximally Stable Extremal Regions) Algorithm: The MSER algorithm is used for text detection and localization. It detects almost all characters from an image and has achieved 88.52% accuracy in character-level recall [9].
Oriented Stroke Detection: This method utilizes oriented stroke detection to detect and localize text. It recognizes a region in the image that has strokes in a particular direction and position. The experimental results showed a recall rate of 66%, which is better than previous methods [10].
Connected Component Clustering and Non-Text Filtering: This method involves connected component clustering and non-text filtering for text detection. It has been used for scene text detection and achieved good results [11].

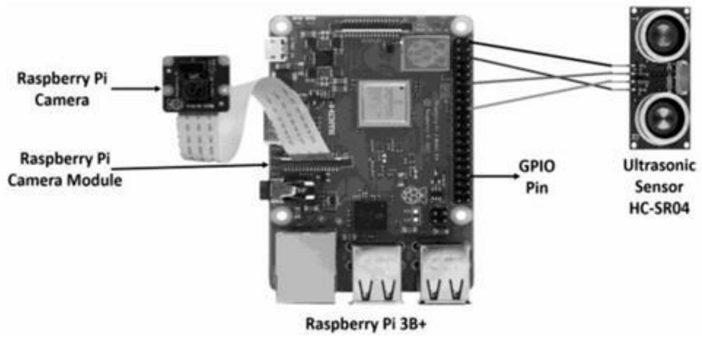

Fig . 1 Basic hardware setup: Raspberry Pi3 ModelB+ and associated module with the camera and ultrasonic sensors [5].

Face Detection

Viola-Jones Algorithm: The Viola-Jones algorithm is a popular face detection method that uses Haar-like features and a cascade classifier [13].
Histogram of Oriented Gradients (HOG): The HOG algorithm is another widely used method for face detection [12]. It computes gradient orientation of image patches represents them as histograms.
Convolutional Neural Networks (CNN): CNNs have revolutionized the field of face detection. They learn hierarchical representations of faces and achieve state-of-the-art performance. CNN-based methods such as the Multi-task Cascaded Convolutional Networks (MTCNN) have been proposed for accurate and efficient face detection [14].
Deep Learning-based Approaches: With the advancements in deep learning, several deep neural network architectures have been proposed for face detection.
Real-time Face Detection: Real-time face detection is crucial for many applications. To address this, parallelization techniques have been explored. For example, the SIFT algorithm has been parallelized on GPUs to achieve real-time performance. Other approaches utilize hardware accelerators such as the NVIDIA Jetson Nano for fast face detection [14].

Vehicle Detection

Histogram of Oriented Gradients (HOG): HOG is a feature descriptor that captures the shape and appearance of objects.It has been widely used for vehicle detection by training classifiers on HOG features [9].
Convolutional Neural Networks (CNN): CNNs have shownremarkable performance in various computer vision tasks, including vehicle detection. They learn hierarchical features directly from raw image data and can achieve high accuracy [9].YOLO (You Only Look Once): YOLO is another popular object detection algorithm that uses a single neural network to predict bounding boxes and class probabilities directly from the input image. It is known for its real-time performance and has been applied to vehicle detection [6].

Distance Detection

S. Zhang, S. Liu, and X. Li," A review on depth estimation and distance measurement techniques," Optik, vol. 127, no. 11, pp. 4848-4856, Jun. 2016. [15] [5] This review paper provides an overview of various depth estimation and distance measurement techniques, including stereo vision, structured light, time-of-flight, and laser-based methods.
Y. Liu, J. Zhang, and Y. Zhang," A survey of depth and distance measurement technologies," in 2017 2nd International Conference on Image, Vision and Computing (ICIVC), Chengdu, China, 2017, pp. 100-104. [16] This survey paper discusses different depth and distance measurement tech, suchas stereo vision, structured light, time-of-flight, and ultrasound,and provides a comparison of their advantages and limitations.
M. A. Hossain, M. S. Hossain, and M. A. Matin," A comprehensive review on distance measurement techniques," in 2018 4th International Conference on Electrical Engineering and Information and Communication Technology (ICEEICT),Dhaka, Bangladesh, 2018, pp. 1-6. [17] This comprehensive review paper presents an overview of distance measurement techniques, including ultrasonic, infrared, laser, vision-based methods, and discusses their applications challenges.
S. S. Kumar, S. S. Kumar, and S. S. Kumar," A survey on distance measurement techniques for autonomous vehicles," in2019 International Conference on Communication and Signal Processing (ICCSP), Chennai, India, 2019, pp. 0642-0646.[18]

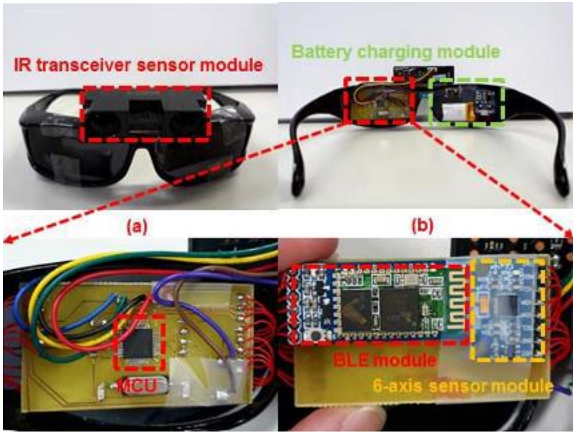

Fig. 2 Prototype of the proposed wearable smart glasses [1].

4. SCOPE:

The scope of this research project encompasses the design, implementation, and evaluation of an assistive system for the visually impaired using a Raspberry Pi 4B 4GB with a cameraversion 1.3. The system integrates various computer vision techniques for face detection, vehicle detection, text detection,and distance measurement using an ultrasonic sensor. Real-time feedback on detected objects is provided to the user through audio output.

Key Components of the Research Scope:

Hardware Integration: Utilizing Raspberry Pi 4B 4GB witha camera version 1.3 as the primary hardware platform for capturing images and videos.

Detection Algorithms: Face Detection: Implementing Haar cascade classifiers and a trained YAML file for accurate face detection.

Vehicle Detection: Employing YOLOv3 for vehicle detection and recognition of objects like stop signs and mobile devices. Text Detection: Utilizing Tesseract OCR for text extraction from images.

Distance Measurement: Using an ultrasonic sensor for measuring distances in the environment.

Evaluation: Testing the system's performance in detecting faces, vehicles, text, and distances accurately. Assessing the effectiveness of the system in assisting visually impaired individuals in their daily activities.

This research project aims to address the challenges faced by visually impaired individuals by providing them with a reliableand efficient assistive system that can enhance their independence and safety in navigating their surroundings effectively.

5. DESIGN:

In the design of the assistive system for the visually impaired, several key considerations were taken into account to ensure its effectiveness and usability.

User-Centric Design: The design process prioritized user needs and preferences, ensuring that the system interface and feedback mechanisms were intuitive and accessible toindividuals with visual impairments.

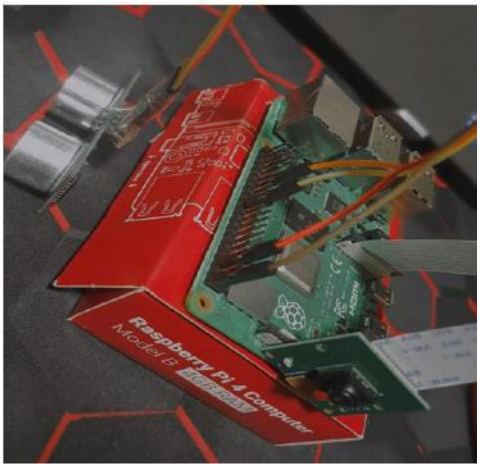

Fig. 3 Connection of Sensors

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Hardware Integration: Carefully integrating the Raspberry Pi 4B 4GB with a camera version 1.3 and an ultrasonic sensor seamlessly into the system architecture to capture images,detect objects, and measure distances effectively.
Detection Algorithms: The selection and implementationof detection algorithms such as Haar cascade classifiers for face detection, YOLOv3 for object recognition, Tesseract OCRfor text extraction vehicle detection were critical in enabling accurate and real-time object detection.

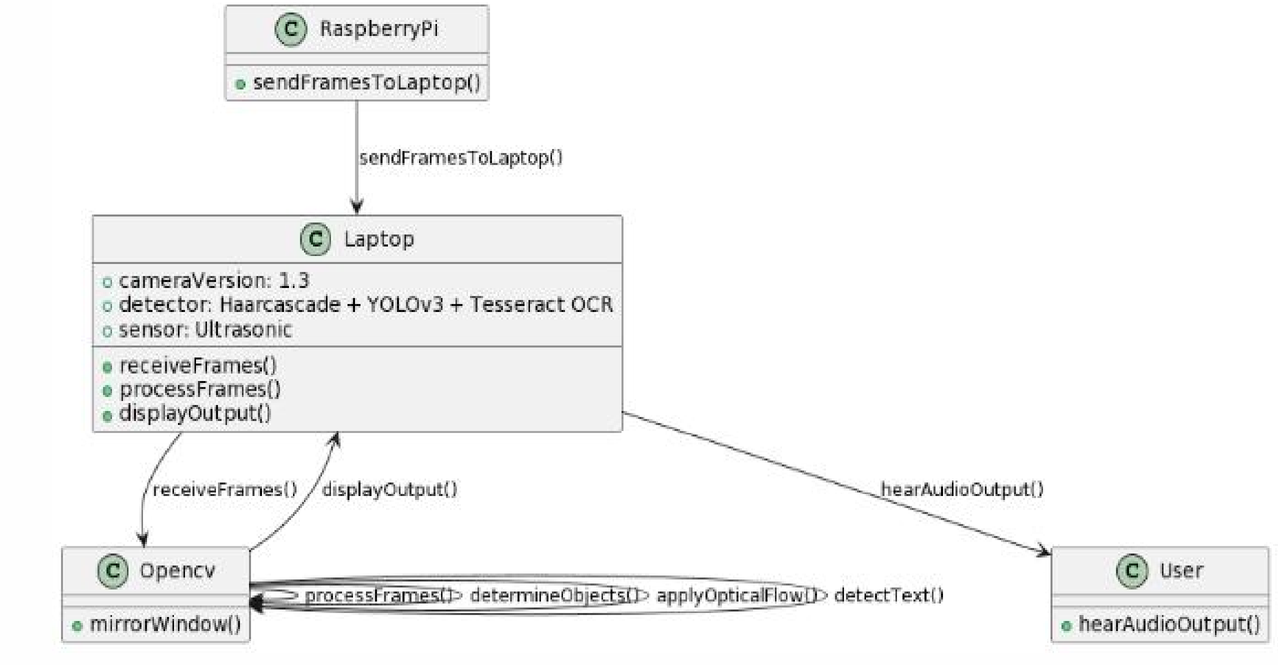

Fig. 4 Data Flow

6. IMPLEMENTATION:

The implementation of the assistive system for the visually impaired involves a series of steps to integrate the hardware components and to develop the detection algorithms, process real-time data, and provide feedback to the user the steps are implementation steps:
Hardware Setup:
Raspberry Pi Configuration: Setting up Raspberry Pi 4B 4GB with a camera version 1.3 (Here we choose these parts but other hardware components can be selected too based on the requirements). Installed necessary libraries and dependencies for camera access and communication.
Ultrasonic Sensor Integration: Connected and calibrate the ultrasonic sensor for accurate distance measurement and placethem in proper GPIO pin to take and give proper input and output.
Camera Integration: Integrated the camera module in theRaspberry Pi's CSI port to take the real time video feed
Software Development:
Face Detection: Implemented Haar cascade classifiers and load the trained YAML file for face detection.
Vehicle Detection and Object Recognition: Integrated YOLOv3 for vehicle detection and recognition of objects like stop signs and mobile devices also yolo3 has a coco name of various objects readily available.
Vehicle Approach Detection: Determine approaching vehicles and detect moving vehicles (List of vehicles include cars, motorbike, buses and trucks).
Text Detection: Utilize Tesseract OCR for text extraction from real time feed captured by the camera and reading itout.
Audio Feedback System: Developed an audio output mechanism to provide real-time feedback on detected objects to the user in such a way that the audio feedback is clearly understandable to the wearer.
Performance Testing: Test the system's performance in detecting faces, vehicles, text, and distances accurately.

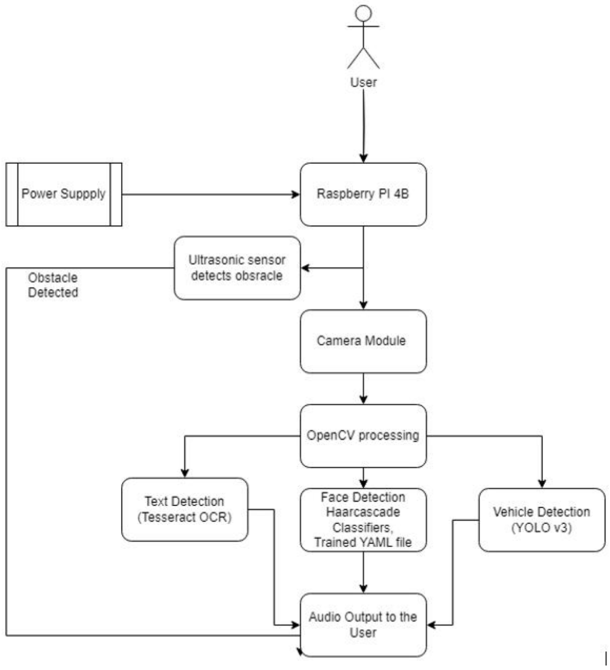

Fig. 5 Flow Chart

7. RESULT:

The results of the implemented assistive system for thevisually impaired showcase its performance in detecting various objects, distances, and providing real-time feedbackto the user. The system's accuracy, efficiency, and usability were evaluated through testing and user feedback.

Detection Accuracy:

Face Detection: The Haar cascade classifiers and trained YAML file demonstrated high accuracy in detecting faces in different lighting conditions and orientations.

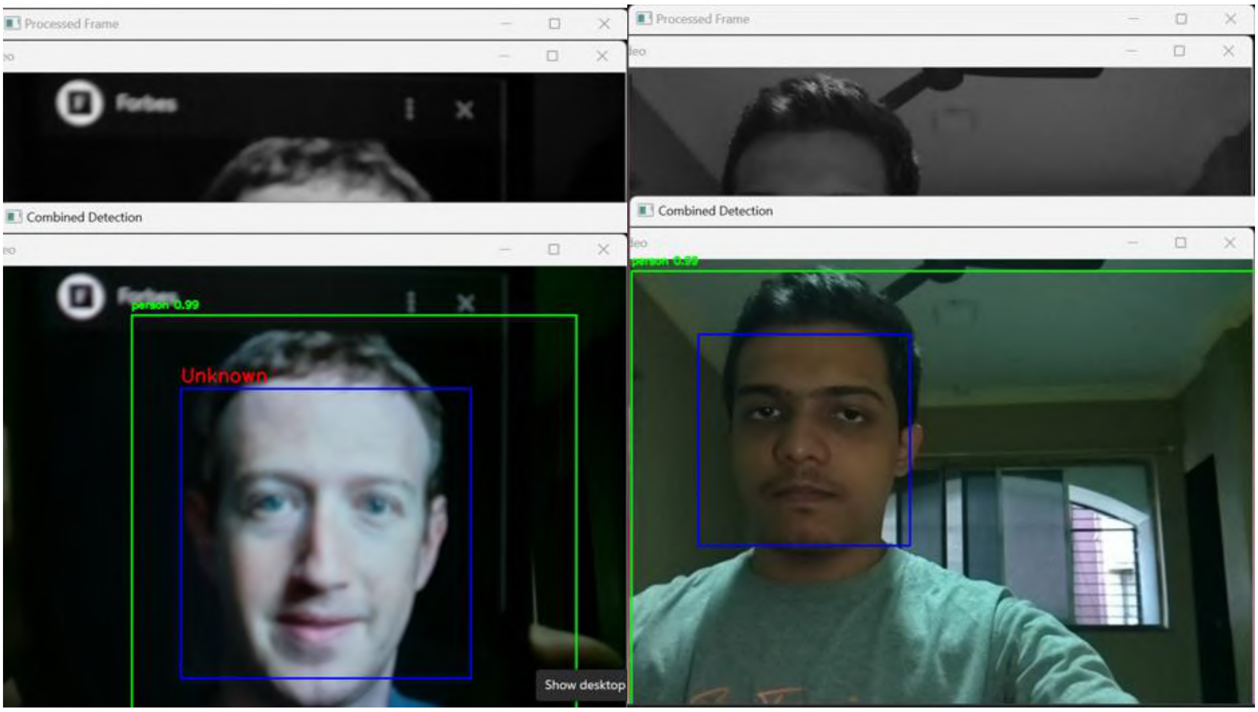

Fig. 6 Face Detection System

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Vehicle Detection and Object Recognition: YOLOv3 accurately detected vehicles and recognized objects like stop signs and mobile devices with a high degree of precision

Fig. 7 Vehicle Detection System

Text Detection: Tesseract OCR successfully extracted textfrom images, enabling the system to provide information on written content in the environment.
Distance Measurement: The ultrasonic sensor accurately measured distances, allowing the system to alert the user to obstacles or objects within a specified range of 50 cm.
Audio Output: The audio feedback mechanism effectively relayed information on detected objects to the user in real-time, enhancing situational awareness.

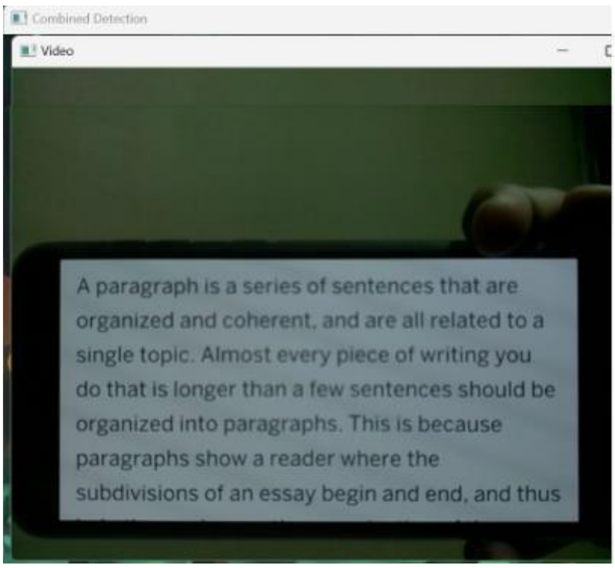

Fig. 8 Text Detection System

8. DISCUSSION:

The implementation and results of the assistive system for the visually impaired signify a significant stride towards leveraging technology to enhance independence and safety forindividuals with visual impairments. By integrating computer vision techniques like Haar cascade classifiers, YOLOv3, and Tesseract OCR, the system demonstrates the potential of advanced algorithms in assisting visually impaired individualsin real-time object detection and distance measurement. Whilethe system's accuracy in detecting faces, vehicles, text, and distances is commendable, further refinement is essential to improve performance in complex environments. Designing an intuitive user interface remains crucial for seamless interactionand usability.

9. FUTURE SCOPE :

The current system is limited to detecting faces, vehicles, text, and distances within a specific range. Expanding the system's capabilities to detect a wider range of objects and distances would greatly enhance its usefulness for visually impaired individuals. Even though raspberry pi comes with 4GB ram, we found it difficult to perform all the operations on board on the raspberry pi , as a result raspberry pi lacks the processing power of the processing . Legacy version of camera module proves to be a difficult challenge to integrate the system setting up the config file in bullseye was a difficult to use raspicam. While the system demonstrated high accuracy in detecting objects, further refinement is needed to improve detection in complex environments or under challenging conditions. This can be achieved by incorporating additional training datasets, fine-tuning the algorithms, and implementing advanced machine learning techniques for adaptive object recognition.

Advances in machine learning: The accuracy and speedof object and text identification may be further improved by integrating modern machine learning models and neural networks, making the device even more dependable. Exploringthe device's integration with wearable technologies, such as smart glasses or haptic feedback systems, can improve user convenience and enjoyment. Navigation and Wayfinding: The usefulness of the device may be greatly improved by creatinga strong GPS-based navigation system that offers turn-by-turn directions and real-time location updates.

Voice Assistant Integration: Including voice assistants like Sirior Google Assistant can increase the device's versatility and provide users the freedom to carry out different operations.

Sensory Feedback: Including extra sensory feedback methods,including vibrations or aural signals, can provide users more in-depth knowledge of their surroundings.

Cloud connectivity: Using cloud computing to handle data canimprove the capabilities of the device without requiring major hardware improvements.

10. CONCLUSION:

The development and evaluation of the assistive systemfor the visually impaired represent a significant step towards leveraging technology to enhance independence, safety, and inclusivity for individuals with visual impairments. By integrating computer vision techniques, real-time processing, and audio feedback mechanisms, the system has demonstrated its potential to assist users in detecting objects, faces, text, and distances in their surroundings. While the system has shown promising results, there are limitations that need to be ad- dressed, such as improving detection accuracy, expanding the range of detection. By overcoming these limitations through further research and development efforts, future iterations of assistive systems can continue to make meaningful contributions towards empowering visually impaired individuals to navigate their environments with greater confidence and independence. The ongoing advancement of assistive technologies holds the promise of creating a more accessible and equitable world for individuals with visual impairments, fostering a society that values inclusivity and embraces diversity in all aspects of life.

REFERENCES:

Journal Papers:

1. L. -B. Chen, J. -P. Su, M. -C. Chen, W. -J. Chang, C. -H. Yang and C. -Y. Sie, "An Implementation of an Intelligent Assistance System for Visually Impaired/Blind People," 2019 IEEE International Conference on Consumer Electronics (ICCE), Las Vegas, NV, USA, 2019, pp. 1-2, doi: 10.1109/ICCE.2019.8661943.

2. H. AlSaid, L. AlKhatib, A. AlOraidh, S. AlHaidar and A. Bashar, "Deep Learning Assisted Smart Glasses as Educational Aid for Visually Challenged Students," 2019 2nd International Conference on new Trends in Computing Sciences (ICTCS), Amman, Jordan, 2019, pp. 1-6, doi: 10.1109/ICTCS.2019.8923044.
3. L. -B. Chen, J. -P. Su, M. -C. Chen, W. -J. Chang, C. -H. Yang and C. -Y. Sie, "An Implementation of an Intelligent Assistance System for Visually Impaired/Blind People," 2019 IEEE International Conference on Consumer Electronics (ICCE), Las Vegas, NV, USA, 2019, pp. 1-2, doi: 10.1109/ICCE.2019.8661943.
4. Feng Lan, Guangtao Zhai and Wei Lin, "Lightweight smart glass system with audio aid for visually impaired people," TENCON 2015 - 2015 IEEE Region 10 Conference, Macao, 2015, pp. 1-4, doi: 10.1109/TENCON.2015.7372720.
5. M. A. Khan, P. Paul, M. Rashid, M. Hossain and M. A. R. Ahad, "An AI-Based Visual Aid With Integrated Reading Assistant for the Completely Blind," in IEEE Transactions on Human-Machine Systems, vol. 50, no. 6, pp. 507-517, Dec. 2020, doi: 10.1109/THMS.2020.3027534.
6. P. S. Rajendran, P. Krishnan and D. J. Aravindhar, "Design and Implementation of Voice Assisted Smart Glasses for Visually Impaired People Using Google Vision API," 2020 4th International Conference on Electronics, Communication and Aerospace Technology (ICECA), Coimbatore, India, 2020, pp. 1221-1224, doi: 10.1109/ICECA49313.2020.9297553.
7. S. S. Hussain, D. Durrani, A. A. Khan, R. Atta and L. Ahmed, "In-door Obstacle Detection and Avoidance System for Visually Impaired People," 2020 IEEE Global Humanitarian Technology Conference (GHTC), Seattle, WA, USA, 2020, pp. 1-7, doi: 10.1109/GHTC46280.2020.9342942.
8. "Visual impairment and blindness," http://www.who.int/mediacentre/factsheets/fs282/en/.
9. H. I., Koo, D. H. Kim, "Scene text detection via connected component clustering and non-text filtering" IEEE Transactions on Image Processing, 22(6), pp. 2296-2305.
10. X. C. Yin, X. Yin, K. Huang, H. W. Hao, "Robust text detection in natural scene images" IEEE transactions on Pattern Analysis and Machine Intelligence, 36(5), pp. 970-980, 2014.
11. L. Neumann, J. Matas, "Scene text localization and recognition with oriented stroke detection" Proceedings of IEEE International Conference on Computer Vision, pp. 97-104, 2013.
12. Hanen Jabnoun, Faouzi Benzarti, and Hamid Amiri. "Object detection and identification for blind people in video scene". In: 2015 15th International Conference on Intelligent Systems Design and Applications (ISDA). IEEE. 2015, pp. 363–367.
13. Alex Krizhevsky, Ilya Sutskever, and Geoffrey E Hinton."Imagenet classification with deep convolutional neuralnetworks". In:Advances in neural information process-ing systems. 2012, pp. 1097–1105.
14. Kaiming He et al. "Deep residual learning for image recognition". In:Proceedings of the IEEE conference oncomputer vision and pattern recognition. 2016, pp. 770–778.
15. S. Zhang, S. Liu, and X. Li, "A review on depth estimation and distance measurement techniques," Optik, vol. 127, no. 11, pp. 4848-4856, Jun. 2016.
16. Y. Liu, J. Zhang, and Y. Zhang, "A survey of depth and distance measurement technologies," in 2017 2nd International Conference on Image, Vision and Computing (ICIVC), Chengdu, China, 2017, pp. 100-104.
17. M. A. Hossain, M. S. Hossain, and M. A. Matin, "A comprehensive review on distance measurement techniques," in 2018 4th International Conference on Electrical Engineering and Information and Communication Technology (ICEEICT), Dhaka, Bangladesh, 2018, pp. 1-6.
18. S. S. Kumar, S. S. Kumar, and S. S. Kumar, "A survey on distance measurement techniques for autonomous vehicles," in 2019 International Conference on Communication and Signal Processing (ICCSP), Chennai, India, 2019, pp. 0642-0646.
19. J.Bai,S.Lian,Z.Liu,K.Wang, and D.Liu,"Virtual-blind-road following based wearable navigation device for blind people," IEEE Trans. Consum. Electron., vol. 64, no. 1, pp. 136–143, Feb. 2018.
20. J. Bai, S. Lian, Z. Liu, K. Wang, and D. Liu, "Smart guiding glasses forvisually impaired people in indoor environment," IEEE Trans. Consum. Electron., vol. 63, no. 3, pp. 258–266, Aug. 2017.
21. D. Dakopoulos and N. G. Bourbakis, "Wearable obstacle avoidance electronic travel aids for blind: A survey," IEEE Trans. Syst. Man, Cybern. Part C Appl. Rev., vol. 40, no. 1, pp. 25–35, Jan. 2010.
22. K. Patil, Q. Jawadwala, and F. C. Shu, "Design and construction of electronic aid for visually impaired people," IEEE Trans. Human-Mach. Syst., vol. 48, no. 2, pp. 172–182, Apr. 2018.
23. J. Villanueva and R. Farcy, "Optical device indicating a safe free path to blind people," IEEE Trans. Instrum. Meas., vol. 61, no. 1, pp. 170–177, Jan. 2012.
24. S. L. Joseph et al., "Being aware of the world: Toward using social mediato support the blind with navigation," IEEE Trans. Human-Mach. Syst., vol. 45, no. 3, pp. 399–405, Jun. 2015.
25. B. Jiang, J. Yang, Z. Lv, and H. Song, "Wearable vision assistance system based on binocular sensors for visually impaired users," IEEE Internet Things J., vol. 6, no. 2, pp. 1375–1383, Apr. 2019.