Clearway Companion - An AI Powered Aid for Visually Impaired

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***Abstract*—We propose a blind assisting smart hat equipped with object detection to empower visually impaired individuals. Existing proposals for blind-assisting hats often suffer from narrow functionalities. These projects tend to be either indoor-specific or limited to object detection, lacking featureslike advanced distance estimation or intuitive user interfaces. Additionally, many designs rely on bulky hardware or excessive component integration, raising concerns about comfort and practicality. Our approach embraces a broader vision, incorporating object detection, distance estimation, extra layer of safety by detecting motion from rear end via PIR motionsensor, haptic notifications and user-friendly audio feedback. We prioritize lightweight, accessible hardware, ensuring the hat seamlessly integrates into daily life. This comprehensive approach aims to address the limitations of existing solutions anddeliver a truly impactful assistive device. Through a miniature camera and machine learning, the hat recognizes everyday objects and hazards, providing audio feedback and distance information. This aims to increase independent navigation, boost spatial awareness, and enhance safety and confidence, ultimately improving quality of life and social inclusion for the visually impaired. By combining hardware design, software development, and user testing, we strive to create a reliable,comfortable, and effective assistive device.**

Keywords - Artificial intelligence; Hardware systems; Assistive technology; Object detection; Blind assistance; Audio feedback; Spatial awareness; Haptic feedback

I. Introduction

World Health Organization estimates 2.2 billion people globally have a vision impairment, with 217 million experiencing blindness [1]. Many struggles with independent navigation, facing increased risk of falls, injuries, and social isolation. These studies provide compelling evidence of the need for advanced blind assisting devices, like your proposed hat, that address current limitations and promote greater independence, safety, and well-being for visually impaired individuals.

Compared with the non-disabled, blind people who have lost visual function become more dependent on other sensations, such as tactile sensation and auditory sensation. Therefore, different types of wearable devices using tactile sensations to transmit information about obstacles have been proposed to assist visually impaired people [2].

The standard of living is significantly impacted by vision impairment in adults. Adults with visual impairment frequently have decreased workforce participation and productivity levels as well as greater rates of anxiety or depression. Older people can be prone to a higher risk of falling due to vision impairment. Similarly, they may feel difficulty in walking anddoing daily tasks, and are socially isolated, which may leadto early admission into nursing or care facilities [1].

This innovative device goes beyond basic obstacle detection. It leverages cutting-edge technology to empower users with a multifaceted suite of features: • Enhanced Object Recognition: Expand beyond basic indoor elements, identifying diverse objects and hazards in real-time. • Precise Distance Estimation: Gauge the relative distance of detected objects, fostering confident navigation and decision-making. • Intuitive Audio Feedback: Receive clear and concise voice instructions tailored to your preferences. • Lightweight and Accessible Design: Experience comfort and seamless integration into daily life. Our Smart Hat for the Visually Impaired harnesses the power of YOLOv4, a state-of-the-art object detection algorithm, paired with the flexible Darknet framework. This potent combination forms the core of our hat's object recognition capabilities. It operates within the Darknet framework, known for its speed, efficiency, and adaptability to various hardware configurations. This allows for deployment on the hat's embedded system, ensuring seamless and real-time object recognition on the go.

Our model training incorporates a dataset comprised of real-time images captured from our college environment, encompassing both indoor and outdoor locations. This initial focus on our college campus allows for controlled data collection and refinement before potential expansion to broader environments. Additionally, we leverage the PyTorch framework for model development and training, capitalizing on its flexibility and efficiency for deep learning tasks.

At the heart of the Smart Hat's object detection capabilities lies a powerful 5MP Raspberry Pi camera. Integrated with a robust Raspberry Pi 4 boasting 8GB of RAM, this camera captures real-time visuals for processing by. This ensures accurate and swift identification of objects and potential hazards in the user's surroundings. To complement the camera's vision, an ultrasonic sensor provides precise distance measurements of detected objects, fostering even greater spatial awareness. Additionally, a PIR motion sensor on the rear side and an ERM vibration motor offering haptic feedback through Bluetooth connectivity work in tandem to enhance safety and user experience. This carefully considered hardware configuration positions the Smart Hat as a reliable and valuable tool for visually impaired individuals seeking greater independenceand confidence in their daily lives.

II. Literature Survey

A review immerses you in the existing research and knowledge base surrounding the topic. This helps to understandthe key concepts, theories, methodologies, and debates within respective field. The review also helps you establish your theoretical framework by identifying relevant theories and models that underpin your research and guide your analysis.

The paper proposed by Muhammad Siddique Farooq et al [1] introduces an innovative solution in the field of assistive technology for visually impaired individuals. Their "IoT Enabled Intelligent Stick for Visually Impaired People for Obstacle Recognition," integrates advanced features to enhance mobility and obstacle recognition. The device incorporates a water sensor for detecting wet surfaces and a high-definition video camera with object recognition capabilities. Notably, it can detect obstacles within a range of 3.5 meters, automatically filtering out objects beyond this distance. However, the system has limitations in detecting objects from behind and is primarily designed for recognizing objects in crowded environments, including vehicles traveling at speeds greater than 30 km/h. This technology represents a significant advancement in assisting visually impaired individuals with navigation challenges. However, further research and development are needed to address its limitations and enhance its effectiveness in various real-world scenarios.

In [2] Junjie Shen et al proposed "Wearable Assistive Device for Blind Pedestrians Using Real-Time Object Detection and Tactile Presentation," emerged as another significant advancement in assistive technology for visually impaired individuals. This wearable device utilizes a tactile presentation systemthat incorporates Shape Memory Alloys (SMA) and vibration motors to provide real-time object detection and information presentation through tactile sensations. However, experiments conducted with this device revealed challenges, including subjects experiencing collisions, especially in more complex situations, and initial user confusion. Addressing these issues and refining its performance are key areas of focus for future work.

Ricardo Tachiquin et al introduced the "Wearable Urban Mobility Assistive Device for Visually Impaired Pedestrians Using a Smartphone and a Tactile-Foot Interface" [5]. This device combines a smartphone with a wearable tactile display, offering haptic feedback through a device inserted into the user's shoe, eliminating the need for manual interaction. Notably, the mean recognition rates for different directions were impressive, though users reported stopping when tactile patterns were displayed. To address this, future work aims to make the tactile patterns shorter and display "forward" instructions during long straight paths.

Recently i.e in 2023, the "Deep Learning Based Object Detection and Surrounding Environment Description for Visually Impaired People," introduced by Raihan Bin Islam, et al. [3], presented a novel approach in assistive technology. This device incorporates ambiance modes and audio feedback to assist users, achieving a detection accuracy of 88.89

This paper proposes the "Real-Time Scene Monitoring for Deaf-Blind People," developed by Khaled Kassem et al. in September 2022 [8]. Their device is designed to detect moving people, bicycles, cars, room entries, and inanimate objects or animals, aiming to enhance the perception of the surrounding environment for deaf-blind individuals. Future development efforts will focus on fine-tuning the haptic feedback motors for individual user suitability and expanding the range of sensors for a more comprehensive monitoring capability.

Sibi C. Sethuraman et al [9] proposes "MagicEye: An Intelligent Wearable Towards Independent Living of Visually Impaired". MagicEye features a custom-trained CNN-based object detection model capable of recognizinga wide range of indoor and outdoor objects commonly encountered in daily life, with 35 classes for high efficiency and precision. The device also includes facial recognition and currency identification modules, aiding the visually impaired. Additionally, MagicEye is equipped with GPS for navigation and a proximity sensor for detecting nearby objects without physical contact.

III. Materials and Methods

3.1 Feasibility Analysis:

Feasibility analysis is mentionedin project management to assess the practicality and viability of a proposed project before committing significant resources to it. It helps project managers and stakeholders understand if the project is achievable within the constraints of time, bud- get, resources, and technology. Feasibility analysis typically includes examining the technical, operational, economic, legal,and scheduling aspects of the project to determine if it is worthpursuing. It helps in making informed decisions about whether to proceed with the project, modify its scope, or abandon it altogether based on the likelihood of success.

This project has been tested in the following areas of feasibility:

1. Technical feasibility
2. Economic feasibility
3. Operational feasibility

1) Technical Feasibility: a. Hardware: Raspberry pi camera 5MP, Raspberry pi 4, ultrasonic sensors, PIR motion sensor and ERM Vibration Motor are readily available and can be integrated into a hat. b. Object detection algorithms: Advancements in computer vision and machine learning enable object recognition with reasonable accuracy. Uses yolo4 and darknet framework. c. Audio feedback: Text-to-speech technology can convert object information into audio cues for the user. d. Processing power: Edge computing devices can handle basic object detection tasks on the hat itself that includes Raspberry pi 4.

2) Economic Feasibility:

a. Hardware Components: Calculating the costs of Raspberry Pi camera, Raspberry Pi 4, sensors, motion detectors, and any other necessary hardware. b. Software Development: Object Detection Algorithms (Using YOLO4 and Darknet Framework). c. Audio Feedback System (Text-to-Speech Technology): Integrating text-to-speech functionality can vary in cost based on the chosen technology or APIs.

3) Operational Feasibility: a. Implementation: Smart Hat can be implemented within a reasonable time frame is achievable, thanks to the availability of necessary hardware like Raspberry Pi devices, sensors, and object detection algorithms. b. User Acceptance: The Smart Hat's functionality, including object detection, audio feedback, and processing power, meets the requirements and expectations of visually impaired users, ensuring high user acceptance and adoption. c. Scalability: The Smart Hat's design allows for scalability, enabling future upgrades and enhancements to accommodate evolving technology and user needs.

3.2 Requirement Analysis

Requirements analysis, also known as requirements engineering, is the foundational step in any project, product, or system development. It's essentially the process of uncovering and understanding the needs, expectations, and constraints involved in bringing that concept to life.

3.2.1 Functional Requirements

i) Hat-

Fig. 1. Smart Hat

Fig. 2. Ultrasonic Sensor and Camera on Smart Hat

ii) Raspberry PI 4-

The Raspberry Pi 4 has USB 3.0 connections, electricity over USB Type-C and Ethernet, video output that can ac- commodate two 4K monitors at the same time, and camera connection connectors. You also have access to the Pi's GPIO pins for communication and extension, as well as compatibilitywith add-ons and accessories.

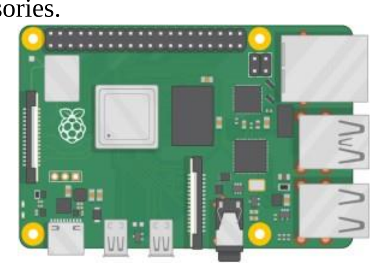


Fig. 3. Raspberry Pi 4

iii) Raspberry Pi Camera-

The Raspberry Pi Camera Module contains a 5-megapixel Sony IMX219 sensor that can capture both high-definition video and still images.

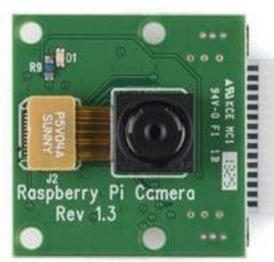


Fig. 4. Raspberry Pi Camera

iv) Ultrasonic Sensor-

An ultrasonic sensor is a device that uses ultrasonic sound waves to determine the distance between two objects. An ultrasonic sensor employs a transducer to send and receive ultrasonic pulses that relay information about the proximityof an item. It estimates the distance between the object andthe sensor by calculating the time taken for the sound wavesto reach the receiver.

Fig. 5. Ultrasonic Sensor

v) ERM Vibration Motor-

The Eccentric Rotating Mass vibration motor, also known as a pager motor, is a direct current (DC) motor with an offset (non-symmetric) mass coupled to the shaft. As the ERM turns, the offset mass's centripetal force is unbalanced, resulting in a net centrifugal force, which forces the motor to move. The motor is constantly displaced and moved by these asymmetric forces due to its high number of revolutions per minute. A vibration is seen as this recurrent displacement.

Fig. 6. ERM Vibration Motor

vi) PIR Motion Sensor-

PIR sensors detect motion and are virtually always usedto determine if an object has moved within or out of thesensor's range. PIRs are built around a pyroelectric sensorthat detects quantities of infrared radiation. Everything emits some low-level radiation, and the higher the temperature, the more radiation is emitted. It has a 6-metre sensitivity range.

Fig. 7. PIR Motion Sensor

vii) Jumper Wires-

Jumper wires are simply wires with connector pins on each end so they can be used to connect two points without soldering. Jumper wires are often used with breadboards and other prototyping tools to make it easier to modify the circuit as needed.

Fig. 8. Jumper Wires

3.2.2 Non-Functional Requirements

i) Reliability This system is reliable and can accurately detect and classify objects in various environmental conditions (e.g., different lighting, weather conditions, front and rear view).

ii) Scalable The system is scalable to accommodate future updates or additional features without significant redesign or performance degradation.

iii) Real Time Processing The system is capable of real- time processing to provide timely feedback to the user about detected objects.

iv) Portability The smart hat is lightweight and comfortable to wear for extended periods, ensuring ease of use for the user.

v) Battery Life The system has sufficient battery life to support continuous use throughout the day without frequent recharging.

vi) User Interface The user interface should be intuitive and easy to understand for blind users, possibly incorporating audio or haptic feedback for interaction.

3.3 System Analysis

System analysis is a critical process that involves under- standing, defining, and documenting the requirements and functionalities of a system. It plays a key role in identifying the needs of users and stakeholders, as well as the problems or in-efficiencies in the current system that need to be addressed. By analyzing the current workflow, processes, and technologies, system analysis helps in designing a solution that meets these requirements and improves the overall system performance. Additionally, it enables cost and time estimation for system development, as well as the identification and management of risks associated with the project. System analysis also facilitates user involvement throughout the development process, ensuring that the final system meets user needs and can be implemented successfully within the specified constraints.

Agile methodology plays a pivotal role in this project for blind assistance by providing a framework that emphasizes flexibility, user-centric design, iterative development, and collaboration. Through Agile, you can adapt to evolving requirements and incorporate feedback from blind individuals and organizations supporting them, ensuring that your smart hat meets their specific needs effectively. The iterative nature of Agile allows you to develop your smart hat in incremental stages, enabling early testing and refinement based onuser feedback. Additionally, Agile's focus on continuous improvement through regular retrospectives enables you to evaluate and enhance your development process, ensuring that your smart hat evolves to address emerging challengesand advancements in assistive technology. Overall, Agile methodologies can help you create a more responsive, user-friendly, and effective smart hat for blind assistance. fostering a dynamic and collaborative development approach. Overall, Agile methodology is used due to its flexibility, iterative nature, and ability to adapt to changing requirements and user feedback. These methodologies can help us delivera functional and user-friendly smart hat for blind assistance more efficiently.

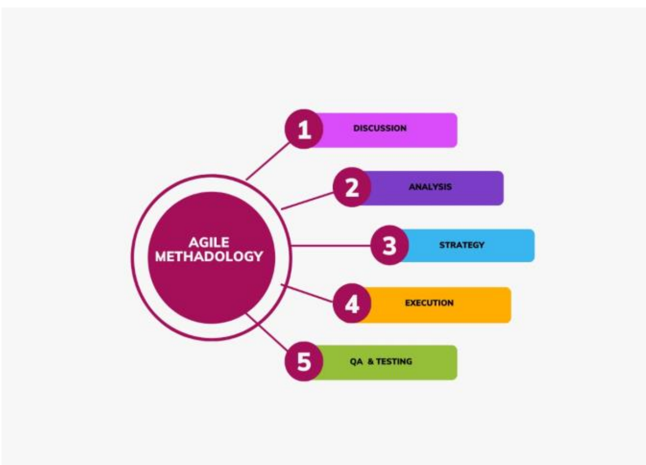


Fig. 9. Agile Methodology

3.4 Hardware and Software Requirements

1. Hardware: a. Raspberry Pi 4 (8 GB storage) b. RaspberryPi Camera (5MP) c. ERM Vibration Motor d. PIR Motion Sensor e. Ultrasonic Sensor f. Jumper Wires g. Bluetoothmodule 5.0 h. Dual band Wi-fi module

2. Software: a. Open CV b. Visual Studio c. PyTorch d. YOLO V4 e. Darknet Framework

3. Programming Language: a. Python

3.5 Overall System Overview

The main aim of our proposed architecture is to provide a robust and scalable solution for blind assistance through the smart hat project. Our architecture is designed to enable real- time object detection using sensors and a Raspberry Pi 4, processing the data to identify objects in the user's environment. The smart hat will then provide audio or haptic feedback to the user, conveying information about the detected objects to enhance their situational awareness and navigation capabilities. Additionally, our architecture focuses on user-centric design, aiming to create an intuitive and comfortable user experience for blind individuals. By leveraging technology and smart sensors, we aim to improve the independence and safety of blind individuals in their daily lives, enhancing their quality of life through innovative assistive technology. Smart hat for blind assistance consists of multiple modules: 1. Sensor Controlling Module: This module includes the sensors (such as ultrasonic sensors, cameras, or PIR motion sensors) used for object detection and environmental sensing. 2. Processing Module: The processing module, likely based on the RaspberryPi 4, handles the real-time processing of sensor data and runs the object detection algorithms. 3. Voice Module: This moduleis responsible for providing feedback to the user based onthe detected objects. It could include audio feedback using speakers or headphones, haptic feedback through vibrations, or a combination of both. 4. Camera Module: This module is responsible for real time capturing of data basically done by Raspberry Pi camera of 5MP. 5. Communication Module: We have communication module for wireless connectivity (e.g., Bluetooth, Wi-Fi) to interact with other devices or to senddata to a companion app.

3.6 Proposed System Architecture

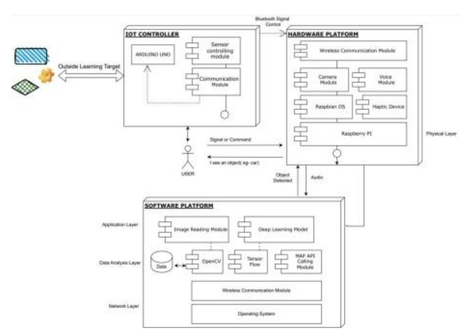


Fig. 10. Block Diagram

3.7 Analysis Model

3.7.1 ER Diagram

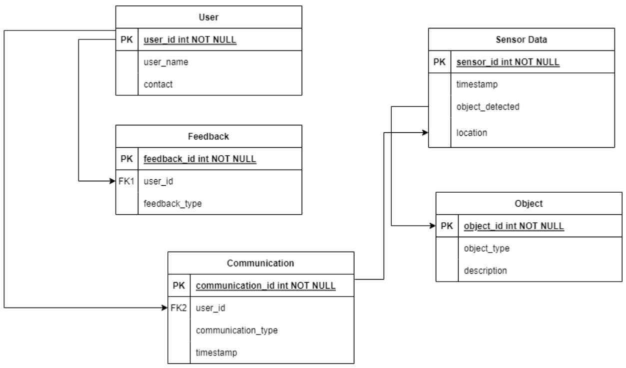


Fig. 11. ER Diagram

3.7.2 Data Flow Diagram (Level 0 and Level 1)

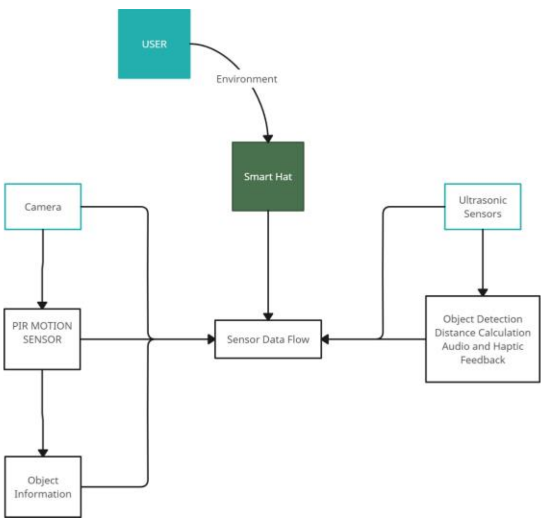


Fig. 12. DFD Level 0

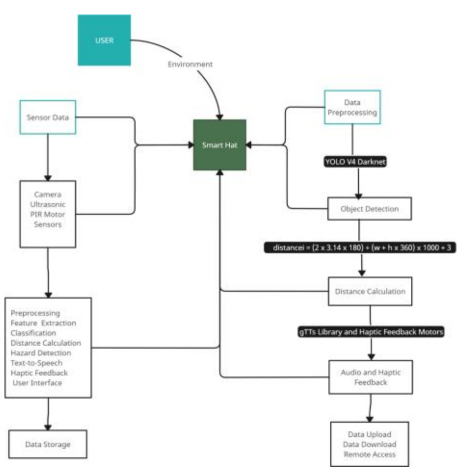


Fig. 13. DFD Level 1

3.7.3 Class Diagram

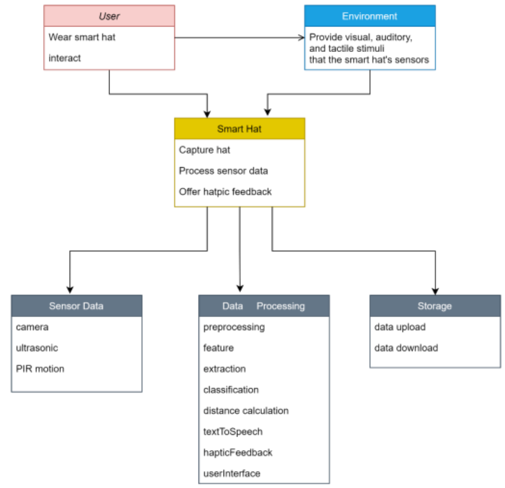


Fig. 13. Class Diagram

3.7.4 Use Case

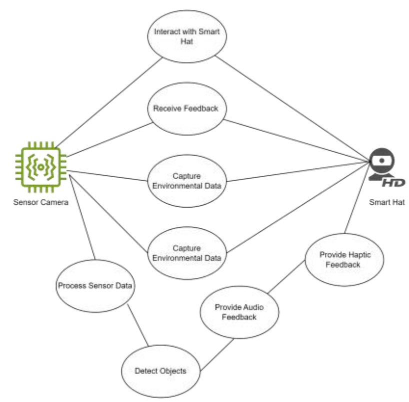


Fig. 14. Use Case

3.7.5 Sequence Diagram

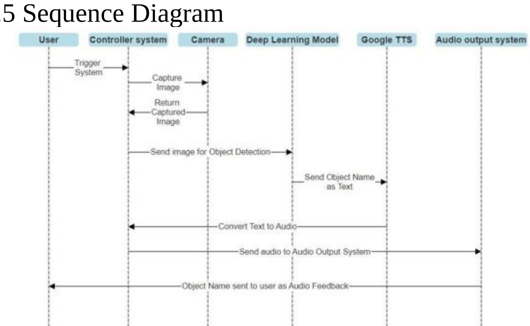


Fig. 15. Sequence Diagram

3.7.6 Activity Diagram

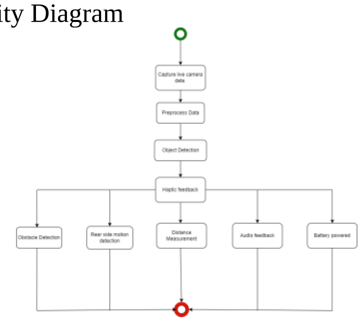


Fig. 16. Activity Diagram

IV. THEORY AND CALCULATIONS

4.1 Analysis Model

4.1.1 Database Description

We developed the Darknet Neural Network model using our proprietary dataset, which we partitioned into two subsets: a training dataset and a testing dataset. The training dataset comprises 492 images and 11 videos, while the testing dataset contains 22 images and validation set contains 43 images. These datasets consist of images of faces, each measuring 48x48 pixels, and underwent preprocessing steps. Auto-Orient was applied to ensure proper orientation, and images were resized to 640x640 pixels. Additionally, augmentation techniques were employed, with each training example yielding three outputs. To enhance robustness, a bounding box noise of up to 5 percent.

YOLOv4 is a state-of-the-art object detection algorithm known for its speed and accuracy. In our project for blind assistance, we have used YOLOv4 to detect and localize objects in real-time using the camera module. PyTorch provides powerful tools for training object detection models, such as YOLOv4. PyTorch is used for preprocessing dataset before training. This might include tasks like resizing images, normalizing pixel values, and augmenting data to increase the diversity of your training set.

4.1.2 Object Detection

Object detection is a crucial component that enhances the user's situational awareness and navigation capabilities. Equipped with a camera module, the smart hat captures live images or video frames of the user's surroundings. Thesevisual data are then processed in real-time using an object detection algorithm, such as YOLOv4, which we have trained using a dataset relevant to blind assistance. This algorithm analyses the visual input to identify and localize objects of interest, such as obstacles, pedestrians, or other environmental features. Based on the detected objects, the smart hat provides feedback to the user, typically through audio cues, haptic vibrations, or other sensory modalities. This feedback alerts the user to the presence of obstacles or other objects in their path, enhancing their situational awareness. By integrating object detection into the smart hat, blind individuals can navigate and interact with their environment more safely and independently, ultimately improving their quality of life.

4.1.3 Distance Detection

Distance detection in our smart hat project for blind assistance involves incorporating sensors and algorithms to estimate the distance between the user and detected objects. This capability is crucial for providing accurate feedback to the user about the proximity of obstacles or other objects in their surroundings. These sensors emit signals and measure the time it takes for the signals to bounce back after hitting an object, allowing for the calculation of distance based on the speed of sound or light. The distance measurements from these sensors need to be processed to filter out noise and errors, ensuring reliable distance estimation. By combining distance detection with object detection, you can localize detected objects in3D space, providing precise feedback about their location and proximity to the user. This information can be conveyedto the user through audio cues, haptic vibrations, or othersensory modalities, with the intensity or frequency of feedbackvarying based on the distance to detected objects. Integrating distance detection into your smart hat enhances its abilityto provide comprehensive and accurate feedback, enabling blind individuals to navigate safely and independently in their environment. This formula is used to determine the distance

$$distance = (2x3.14x180)(w + hx360)x1000 + 3 \quad (1)$$

For measuring distance, at first, we have to understand how a camera sees an object. We can relate this image to the white dog picture where the dog was localized. Again, we will get four numbers in the bounding box which is (x0, y0, width, height). Here x0, y0 is used to tiled or adjust the bounding box. Width and Height these two variables are used in the formula of measuring the object and describing the detailof the detected object/objects. Width and Height will vary depending on the distance of the object from the camera. As we know, an image goes refracted when it goes through alens because the ray of light can also enter the lens, whereas,in the case of a mirror, the light can be reflected. That's why we get an exact reflection of the image. But in the case ofthe lens image gets a little stretched.

4.1.4 Text to Speech

Text-to-speech (TTS) technology is a key component of our smart hat project for blind assistance, enabling the conversion of written text into spoken words. TTS software or libraries are used to synthesize natural-sounding speechfrom textual information. This involves processing the textto generate speech waveforms that mimic human speech patterns, including intonation, rhythm, and pronunciation. The input to the TTS system can be any textual information that you want to convey to the user, such as warnings about detected obstacles, navigation instructions, or environmental descriptions. The output of the TTS system is audio that is played through speakers or headphones worn by the user. This audio feedback provides real-time information about the user's surroundings, helping them navigate safely and independently. TTS can be integrated with your object detection system to provide verbal descriptions of detected objects, enhancing the user's understanding of their environment. Additionally, TTS systems often allow for customization of voice characteristics, such as gender, accent, and speed of speech, to better suit the user's preferences and needs. Overall, integrating TTS into your smart hat enhances its communication capabilities, providing valuable auditory feedback that aids blind individuals in navigating their

4.1.5 Feature Extraction

In the context of our project using Darknet for object detection, feature extraction in Darknet refers to the process of extracting relevant features from input images or video frames to enable the detection and recognition of objects. Darknet, the neural network framework used in YOLOv4, is designed to perform efficient and accurate feature extraction for object detection tasks. This process is achieved through convolutional neural networks (CNNs), which are the backbone of Darknet's architecture. CNNs in Darknet are composed of multiple layers, including convolutional layers, pooling layers, and fully connected layers. These layers work together to automatically extract hierarchical features from the input data. Lower layers of the network extract low-level features such as edges, textures, and colors, while higher layers learn more abstract and complex features that represent object shapes and structures. During the training process, Darknet's CNNs are optimized to learn discriminative features that are useful for distinguishing between different classes of objects. This is achieved through backpropagation, where the network adjusts its weights based on the error between predicted and ground truth labels. The output of the convolutional layers in Darknet is a set of feature maps, which encode spatial information about the presence and location of objects in the input images. These feature maps are then used by Darknet's object detection module to localize and classify objects within the input images. The feature maps are processed further to generate bounding boxes around detected objects and predict their class labels and confidence scores. By leveraging Darknet's efficient feature extraction capabilities, your smart hat can perform real-time object detection with high accuracy, enabling it to detect and recognize objects in the user's environment to assist with navigation and obstacle avoidance.

4.1.6 Algorithm

4.1.6.1 Object Detection

1. Initialise camera
2. Load YOLOV8 Model
3. Load class labels
4. Set confidence threshold
5. Set object_found = FALSE
6. While True do:
i. Img□ camera.read()
ii. Preprocess the image (resize, normalize pixel values)
iii. blob ← cv2.dnn.blobFromImage(img, scalefactor=1/255.0, size=(416,
416), swapRB=True, crop=False)
iv. net.setInput(blob)
v. outs ← net.forward(output_layers)
7. for each out in outs do:
8. for each detection in out do:
i. scores ← detection [5:]
ii. class_id ← argmax(scores)
9. confidence ← scores[class_id]
10. if confidence > confidence_threshold then:
i. Set object_found = True
ii. box ← detection[0:4] * np.array([img_width, img_height, img_width,
img_height])
iii. (x, y, w, h) ← box.astype("int")
iv. Draw bounding box on img
v. Put text with class label and confidence on img at (x, y-5)
vi. Show image(img) with bounding boxes and text.

4.1.6.2 Text to Speech

1. Import Required Libraries i. Import the necessary libraries, including gTTS for text-to-speech conversion and pygame for audio playback.
2. Initialize Pygame Mixer i. Initialize the pygame mixer to handle audio playback.
3. Define a Text-to-Speech Function: i. Create a function that takes text as input. ii. Use gTTS to convert the text to speech and generate an audio stream. iii. Save the audio stream to a object.
4. Load and Play the Audio: i. Load the audio stream using pygame mixer. ii. Play the audio using pygame.mixer.music.play(). iii. Wait until the audio finishes playing using pygame.mixer.music.get_busy().
5. Call the Text-to-Speech Function: i. Call the text-to-speech function with the desired text to convert it to speech and play the audio.

4.1.6.3 Distance Calculation

1. Initialize Ultrasonic Sensor:
i. Connect the ultrasonic sensor to the microcontroller.
ii. Initialize the ultrasonic sensor pins for trigger and echo.
2. Trigger Ultrasonic Pulse:
i.Send a short high pulse (10 microseconds) to the trigger pin of the ultrasonic sensor.
ii. This pulse triggers the ultrasonic sensor to send out an ultrasonic wave.
3. Measure Echo Pulse Duration:
i. Measure the duration for which the echo pin of the ultrasonic sensor stays high.
ii. This duration corresponds to the time taken for the ultrasonic wave to travel to the object and back.
4. Calculate Distance:
i. Convert the echo pulse duration to time in seconds (e.g., microseconds to seconds).
ii. Use the speed of sound in air (approximately 343 meters per second) to calculate the distance travelled by the ultrasonic wave.
5. Display or Use Distance:
i. Display the calculated distance on an LCD display, serial monitor, or other output interface.
ii. Use the distance measurement for various applications like obstacle avoidance, object detection, or distance monitoring.

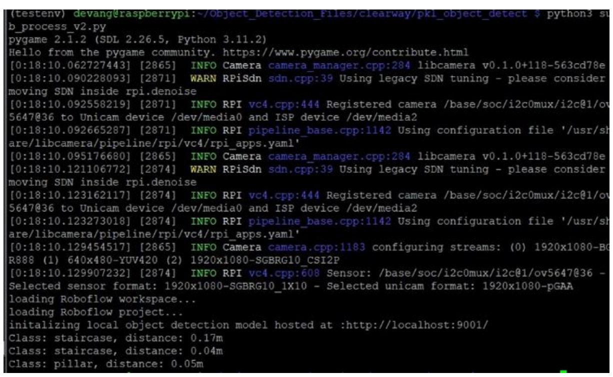
V. RESULTS AND DISCUSSION

In this chapter, the preliminary results and discussions regarding the feasibility of the smart hat for visually impaired individuals are presented. Our testing phase honed in on how well the Smart Hat could detect and recognize objects accurately. Impressively, our results show that the advanced technology within the Smart Hat successfully identified various objects and obstacles along the path from the main college gate to room no. 207, which served as our testing ground.

Feedback from our public testing and consultations with professors shed light on the Smart Hat's user-friendly design. Users found it easy to set up, navigate, and customize, highlighting its effectiveness in catering to their needs.

One standout feature was the real-time processing of environmental data, allowing the Smart Hat to provide immediate feedback and support in different urban environments. Users were particularly pleased with the system's quick responses, which greatly enhanced their overall navigation experience.

Throughout our testing and discussions, the Smart Hat's focus on enhancing safety and independence within the college premises became evident. Its capability to navigate challenges such as crowded pathways and varying environmental conditions received positive feedback from both users and experts.



```
(testenv) devang@raspberrypi:~/Object_Detection_Files/clearway/pkl_object_detect $ python3 su
b_process_v2.py
pygame 2.1.2 (SDL 2.26.5, Python 3.11.2)
Hello from the pygame community. https://www.pygame.org/contribute.html
[0:18:10.062727443] [2865]  INFO Camera camera_manager.cpp:284 libcamera v0.1.0+118-563cd78e
[0:18:10.090228093] [2871]  WARN RPiSdn sdn.cpp:39 Using legacy SDN tuning - please consider
moving SDN inside rpi.denoise
[0:18:10.092558219] [2871]  INFO RPI vc4.cpp:444 Registered camera /base/soc/i2c0mux/i2c@1/ov
5647@36 to Unicam device /dev/media0 and ISP device /dev/media2
[0:18:10.092665287] [2871]  INFO RPI pipeline_base.cpp:1142 Using configuration file '/usr/sh
are/libcamera/pipeline/rpi/vc4/rpi_apps.yaml'
[0:18:10.095176680] [2865]  INFO Camera camera_manager.cpp:284 libcamera v0.1.0+118-563cd78e
[0:18:10.121106772] [2874]  WARN RPiSdn sdn.cpp:39 Using legacy SDN tuning - please consider
moving SDN inside rpi.denoise
[0:18:10.123162117] [2874]  INFO RPI vc4.cpp:444 Registered camera /base/soc/i2c0mux/i2c@1/ov
5647@36 to Unicam device /dev/media0 and ISP device /dev/media2
[0:18:10.123273018] [2874]  INFO RPI pipeline_base.cpp:1142 Using configuration file '/usr/sh
are/libcamera/pipeline/rpi/vc4/rpi_apps.yaml'
[0:18:10.129454517] [2865]  INFO Camera camera.cpp:1183 configuring streams: (0) 1920x1080-BG
R888 (1) 640x480-YUV420 (2) 1920x1080-SGBRG10_CSI2P
[0:18:10.129907232] [2874]  INFO RPI vc4.cpp:608 Sensor: /base/soc/i2c0mux/i2c@1/ov5647@36 -
Selected sensor format: 1920x1080-SGBRG10_1X10 - Selected unicam format: 1920x1080-pGAA
loading Roboflow workspace...
loading Roboflow project...
initalizing local object detection model hosted at :http://localhost:9001/
Class: staircase, distance: 0.17m
Class: staircase, distance: 0.04m
Class: pillar, distance: 0.05m
```

Fig. 17. Object Detection and Distance Estimation

Fig. 18. Object Detection model testing

5.1 Analysis Parameters

Our assessment encompasses arange of critical parameters, including object detection accu- racy, user-friendliness, real-time feedback capabilities, integration of cutting-edge technologies, safety features, and usabilitytesting with visually impaired individuals.

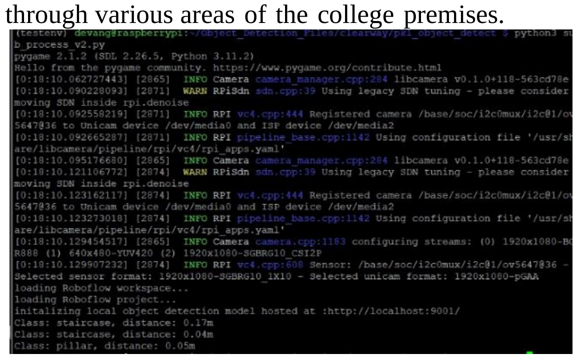
1. Object Detection Accuracy: The first parameter analyzed is the object detection accuracy of the Smart Hat. We conducted tests to measure how accurately the device detects and recognizes various objects and obstacles along the specified path, including walls, furniture, doors, and other environmental elements within the college premises.

Fig. 19. Object Detection via Smart Hat

2. User-Friendliness: Ease of use and accessibility are crucial aspects of the Smart Hat's design. Usability testing was conducted to evaluate how easy it is for visually impaired users to set up, navigate, and customize the device according to their preferences and needs.

Fig. 20. Smart Hat Design

3. Real-Time Feedback and Assistance: One of the key features of the Smart Hat is its ability to provide real-time feedback and assistance. We assessed the promptness and effectiveness of the system's responses in providing immediate feedback and assistance to users navigating through various areas of the college premises.




```
(testenv) devang@raspberrypi:~/Object_Detection_Files/clearway/pkl_object_detect $ python3 su
b_process_v2.py
pygame 2.1.2 (SDL 2.26.5, Python 3.11.2)
Hello from the pygame community. https://www.pygame.org/contribute.html
[0:18:10.062727443] [2865]  INFO Camera camera_manager.cpp:284 libcamera v0.1.0+118-563cd78e
[0:18:10.090228093] [2871]  WARN RPiSdn sdn.cpp:39 Using legacy SDN tuning - please consider
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5647@36 to Unicam device /dev/media0 and ISP device /dev/media2
[0:18:10.092665287] [2871]  INFO RPI pipeline_base.cpp:1142 Using configuration file '/usr/sh
are/libcamera/pipeline/rpi/vc4/rpi_apps.yaml'
[0:18:10.095176680] [2865]  INFO Camera camera_manager.cpp:284 libcamera v0.1.0+118-563cd78e
[0:18:10.121106772] [2874]  WARN RPiSdn sdn.cpp:39 Using legacy SDN tuning - please consider
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5647@36 to Unicam device /dev/media0 and ISP device /dev/media2
[0:18:10.123273018] [2874]  INFO RPI pipeline_base.cpp:1142 Using configuration file '/usr/sh
are/libcamera/pipeline/rpi/vc4/rpi_apps.yaml'
[0:18:10.129454517] [2865]  INFO Camera camera.cpp:1183 configuring streams: (0) 1920x1080-BG
R888 (1) 640x480-YUV420 (2) 1920x1080-SGBRG10_CSI2P
[0:18:10.129907232] [2874]  INFO RPI vc4.cpp:608 Sensor: /base/soc/i2c0mux/i2c@1/ov5647@36 -
Selected sensor format: 1920x1080-SGBRG10_1X10 - Selected unicam format: 1920x1080-pGAA
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initalizing local object detection model hosted at :http://localhost:9001/
Class: staircase, distance: 0.17m
Class: staircase, distance: 0.04m
Class: pillar, distance: 0.05m
```


Fig. 21. Real time detection

4. Performance in Controlled Environment: The Smart Hat's performance under controlled conditions within the college premises was thoroughly assessed to measure its reliability and accuracy in detecting and navigating obstacles, providing a clear understanding of its performance in a controlled environment.

5.2 Test Cases

The user carried out system testing once the completion of the system development. These test cases were carefully crafted to assess key aspects of the device's functionality and user experience, providing valuable insights into its effectiveness in assisting visually impaired individuals.

Test Cases:

TABLE I
TEST CASES

Test Cases	Expected Function	Positive	Negative
Object Detection and Recognition	Accurately detect and recognize objects and obstacles	✓	
Auditory Cues for Object Detection	Announce detected objects through auditory cues	✓	
	Verify system's speed and reliability in identifying objects	✓	
Distance Announcement	Announce distance using ultrasonic sensor	✓	
Haptic Feedback using PIR Motion Sensor and Vibration Motor	Activate vibration motor when motion is detected viathe motion sensor sideways and backside	✓	
User-Friendly Interface	Ensure ease of use for visually impaired users	✓	
Real-Time Feedback	Test real-time processing for immediate feedback	✓	
	Verify promptness of feedback and assistance	✓	
Safety and Independence	Address safety concerns and promote independence	✓	
Usability Testing	Gather user feedback and address usability challenges	✓	

VI. CONCLUSION

Our development of the Clearway Companion, or Smart Hat, for visually impaired individuals, stemmed from a thorough literature review and insights from scientific methods.

Focused on object detection, real-time feedback, and user-friendly interfaces, our aim was to create a solution ensuring safety, independence, and convenience in college environments.

The integration of IoT devices, deep learning algorithms, auditory cues, and haptic feedback significantly elevated the capabilities of the Smart Hat, enriching the overall user experience. Challenges such as managing large datasets spurred ongoing innovation, driving us closer to our ultimate vision of creating an affordable and standardized device that simplifies navigation.

VII. FUTURE WORK

The Clearway Companion represents a fusion of technological advancements and user-centric design principles, underpinned by a steadfast commitment to empowering visually impaired individuals. As we move forward, our dedication remains unwavering—we continue to refine our system, gatheruser insights, and explore novel avenues to enhance accessi- bility, safety, and independence for all users.

1) **Real-Time Environment Mapping:** Implementing real-time environment mapping using SLAM (Simultaneous Localization and Mapping) techniques can provide users with a more detailed understanding of their surroundings.
2) **Path Estimation and Directional Guidance:** Implementing advanced path estimation algorithms will enable the Smart Hat to predict the optimal route from theuser's current location to the destination. Additionally, integrating directional cues into the system will provide real-time guidance, ensuring seamless navigation and enhancing the overall user experience.
3) **Enhanced Object Recognition:** Continuing advancements in deep learning and computer vision techniques can further improve the Smart Hat's object recognition capabilities.
4) **Augmented Reality Integration:** Integrating augmented reality (AR) technology can overlay contextual information and navigation cues directly onto the user's visual field.
5) **Improvement of Distance Detection Module:** Enhancing the distance detection module involves refining the technology and algorithms used to accurately measure distances in real-time.
6) **Commercializing the Smart Hat:** Turning the prototype into a fully-fledged product ready for commercial sale.

VIII. DECLARATION OF COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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We also are thankful to our parents for their constant support and best wishes.

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