CAPSTONE PROJECT REPORT

on

Smart Drishti - AI Powered Assistive Glasses for Visually Impaired

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[2024-2025]

CERTIFICATE

This is to certify that Dhruti Deshpande (1032211792), Aastha Sisodia (1032211929), Pranay Gupta (1032211057) has successfully completed his Capstone Project entitled "Smart Drishti -AI Powered Assistive Glasses for Visually Impaired" and submitted the same during the academic year 2024-25 towards the partial fulfilment of degree of Bachelor of Technology in Electronics and Communication- AIML Engineering as per the guidelines prescribed by Dr. Vishwanath Karad MIT World Pace University, Pune.

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Date: 22/04/2025

Place : Pune

DECLARATION

I/We the undersigned, declare that the work carried under Capstone Project entitled **“Smart Drishti - AI Powered Assistive Glasses for Visually Impaired”** represents my/our idea in my/our own words. I/We have adequately cited and referenced the original sources where other ideas or words have been included. I/We also declare that I/We have adhered to all principles of academic honesty and integrity and have not misprinted or fabricated or falsified any ideas/data/fact/source in my/our submission. I/We understand that any violation of the above will be cause for disciplinary action by the University and can also evoke penal action from the sources which have thus not been properly cited or whom proper permission has not been taken when needed.

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ACKNOWLEDGEMENT

It gives us immense pleasure to present our Project Report on **Smart Drishti - AI Powered Assistive Glasses For Visually Impaired**. This project opportunity gave us a platform to acquire analytical and professional skills. In these months of our project endeavors many people helped us either directly or indirectly in achieving our ultimate goals. Hence, it becomes our moral duty to acknowledge all those individuals.

We would like to thank our Project Guide **Dr. Mrunal Annadate** for always guiding us throughout the project by always helping us out during difficult situations. We were fortunate enough to have a guide with such immense industrial experience. From the very inception of the project, she always made us feel comfortable during our work. Under her guidance, we learnt invaluable lessons in engineering. She would frequently share with us her inputs on making the project more accessible to people with visual impairment keeping in mind the latest trends in the market.

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ABSTRACT

The World Health Organization (WHO) reported that there are 285 million visually impaired people worldwide. Among these individuals, there are 39 million who are totally blind. There have been several systems designed to support visually impaired people and to improve the quality of their lives. Unfortunately, most of these systems are limited in their capabilities.

This Capstone Project introduces a prototype of **Smart Glasses** designed specifically for visually impaired individuals. The glasses integrate computer vision, deep learning, and sensor fusion technologies to enable real-time object detection, obstacle avoidance, and text recognition. The system comprises a Raspberry Pi 4, a global shutter camera module and audio feedback through earphones. The YOLOv5 algorithm is utilized for object detection, while Tesseract OCR and Google Text-to-Speech (gTTS) modules assist in reading and vocalizing printed text.

The proposed smart glasses serve as a wearable assistive device to improve the independence and quality of life of visually impaired users, offering reliable performance in various environments including indoors, outdoors, and dynamic public spaces. The system is scalable, cost-effective, and adaptable for further enhancement with advanced AI models and multimodal interaction.

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ABBREVIATIONS

AI	Artificial Intelligence
NLP	Natural Language Processing
YOLO	You Only Look Once
CNN	Convolution Neural Networks
OCR	Optical Character Recognition

CHAPTER 1
INTRODUCTION

1.1 Motivation

As of 2023, the World Health Organization (WHO) estimates that over 2.2 billion people globally have some form of visual impairment, including partial and complete blindness. This condition disproportionately affects the most vulnerable groups, such as the elderly, people with disabilities, and marginalized communities, limiting their independence and quality of life.

One of the most significant challenges faced by the visually impaired is independent mobility, particularly outdoor navigation. Navigating unfamiliar or obstacle-laden environments without assistance poses risks and creates a barrier to autonomy. Tasks such as object detection, text reading, and safe pathfinding are daily struggles, often requiring external help or expensive, bulky assistive technology.

Despite the advances in AI and wearable tech, there remains a pressing need for a lightweight, intelligent, and user-friendly solution that aids visually impaired individuals in real-time. The solution must function efficiently with or without a smartphone and should seamlessly integrate into the user’s life without being intrusive or complex.

By addressing the lack of accessible, cost-effective, and user-friendly assistive technologies, we aim to empower visually impaired individuals with greater independence and confidence in their daily lives. A solution that supports safe and autonomous navigation will significantly reduce their reliance on others for mobility and routine tasks.

Ultimately, this initiative aspires to foster inclusivity and accessibility, bridging the gap between technological advancement and the real-world needs of the visually challenged community. It is a step forward in building a more equitable society where everyone, regardless of ability, can navigate the world with dignity and ease.

1.2 Organization Of Report

This report is structured into the following chapters:

- Chapter 2: Review of Literature
  Provides an overview of existing technologies, research work, and methodologies related to assistive devices for the visually impaired.
- Chapter 3: System Development
  Describes the overall architecture, block diagram, and hardware components used in the smart glasses system.
- Chapter 4: System Implementation
  Explains the step-by-step process of building both the hardware and software aspects, including algorithm details and flowcharts.
- Chapter 5: Results and Analysis
  Discusses the observed performance of the system, including object detection accuracy, response time, and feedback quality.
- Chapter 6: Discussion and Conclusion
  Summarizes the achievements of the project, challenges encountered, solutions applied, and scope for future work.
- Chapter 7: Individual Contributions
  Highlights the specific roles and tasks handled by each team member.
- Chapter 8: References
  Lists all the research papers, tools, and online resources referenced during the project.

CHAPTER 2
REVIEW OF LITERATURE

2.1 Literature review

The evolution of assistive technology for the visually impaired has undergone a transformative journey. Initially limited to tactile tools such as Braille and mobility aids like white canes or guide dogs, the domain has rapidly advanced with the advent of intelligent electronic systems. These include sensor-based solutions, wearable devices, and AI-enabled systems that allow users to perceive and interpret their surroundings in ways previously unimaginable.

A significant milestone in the development of assistive systems was achieved through the integration of ultrasonic sensors, IR sensors, and microcontrollers. As studied by Elmannai and Elleithy (2017), these systems enhanced basic mobility by detecting static obstacles in the user's immediate path. However, their utility was often limited by range, ambient noise interference, and inability to process dynamic scenarios involving moving objects.

Computer Vision (CV) further advanced the field. The transition from simple camera-based systems to robust, real-time image recognition was enabled by deep learning models like Convolutional Neural Networks (CNNs), Region-based CNNs (R-CNN), and You Only Look Once (YOLO). YOLOv5**, in particular, has emerged as one of the most efficient object detection algorithms due to its balance of accuracy and inference speed. As demonstrated in Gollagi et al. (2023), YOLOv5 was instrumental in creating wearable vision systems capable of detecting and naming everyday objects like furniture, street signs, and even people.

In tandem, Optical Character Recognition (OCR) has seen remarkable improvements. OCR systems began with simple pattern recognition and evolved to sophisticated open-source engines like Tesseract, capable of multi-language support, curved text handling, and document layout detection. These systems empower users to read signs, labels, and printed material. For instance, EnableMart's text-to-speech devices have been used to convert printed text into speech, although without deep contextual understanding.

To improve user interaction, Natural Language Processing (NLP) technologies have been deployed to interpret user commands and provide spoken descriptions of surroundings. The study by Brilli (2024) introduces "AIris," a smart glass that uses image captioning, object tracking, and NLP-based summarization. This allows not only detection but also narration—"There is a table to your left" or "A red car is passing by"—offering contextual insight instead of raw data.

Scene understanding has also evolved. Liu et al. (2020) explain how semantic segmentation and multi-object recognition allow systems to classify the environment as indoor, outdoor, busy, or calm—adapting feedback accordingly. Such systems are trained on datasets like

COCO, ImageNet, or OpenImages, improving their recognition capabilities across varied environments and scenarios.

A study by Tanaka and Hashimoto (2023) experimented with sensor fusion by combining LiDAR, IR, and ultrasonic sensors for 3D spatial awareness. Their research found significant improvements in spatial mapping accuracy and reaction time, but power consumption remained a limitation for wearable applications.

Human-Centered Design (HCD) is another pillar of innovation. Research by Kleege (2014) emphasizes designing interfaces that align with how visually impaired individuals conceptualize space—through touch, sound, and imaginative visualization. Personalized feedback, multisensory outputs, and adaptability to user pace are gaining traction.

Moreover, studies like those by Jordan and Smith (2023) explore the use of AI-powered pedestrian tracking, pathfinding, and voice-guided navigation in crowded environments like airports and malls. Their implementation used lightweight neural networks for edge computing, though it required additional optimization to handle high-volume data in real time.

Commercial tools such as OrCam, Envision Glasses, and Microsoft's Seeing AI have demonstrated the real-world viability of smart assistive glasses. However, high cost, limited availability in developing countries, and dependency on cloud-based services restrict their universal adoption.

In conclusion, the literature strongly supports the feasibility and societal value of smart glasses that integrate real-time object detection, text reading, and obstacle avoidance. Despite current limitations like latency, battery life, and user adaptability, continuous research and open-source development are pushing boundaries toward more accessible and efficient solutions.

This project takes inspiration from these prior works and aims to deliver a scalable, cost-effective, and real-time wearable solution that bridges the current gaps, especially for deployment in resource-constrained settings.

2.2 Aim and Objective

Aim:

To design smart glasses that assist visually impaired individuals in real-time navigation, obstacle detection, and text recognition.

Objectives:

1. To design a wearable system using Raspberry Pi and compatible sensors and camera modules.
2. To implement YOLOv5 for efficient and real-time object detection.
3. To utilize Tesseract OCR for extracting textual information from surroundings.
4. To provide auditory feedback using Google Text-to-Speech (gTTS).
5. To test the system's performance in varied environments including indoor, outdoor, and crowded spaces.
6. To develop a user-friendly, modular, and cost-effective system that can be scaled and enhanced in future versions.

CHAPTER 3

SYSTEM DEVELOPMENT

3.1 System Block Diagram

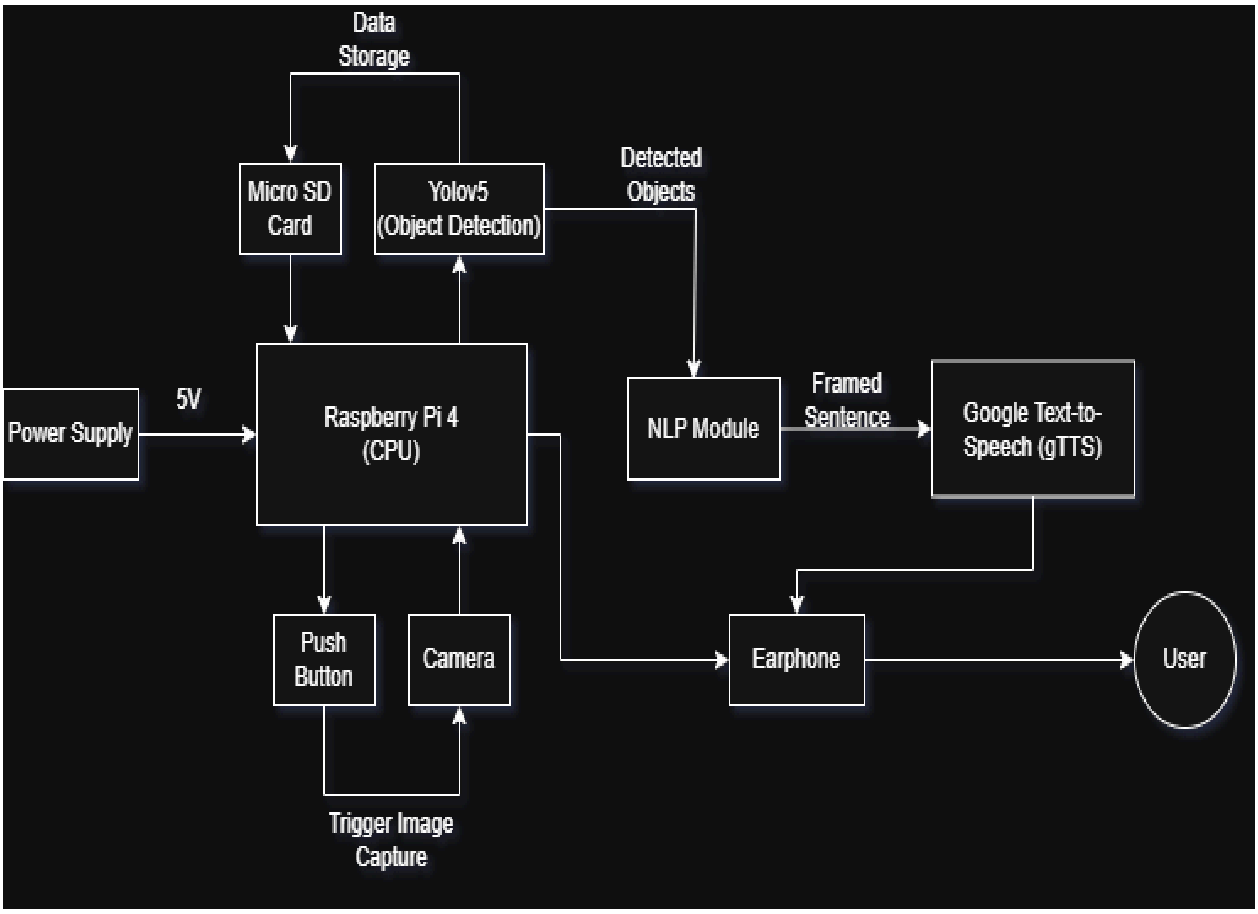

Figure 1: Block Diagram

3.2 System Specifications

Hardware Requirements:

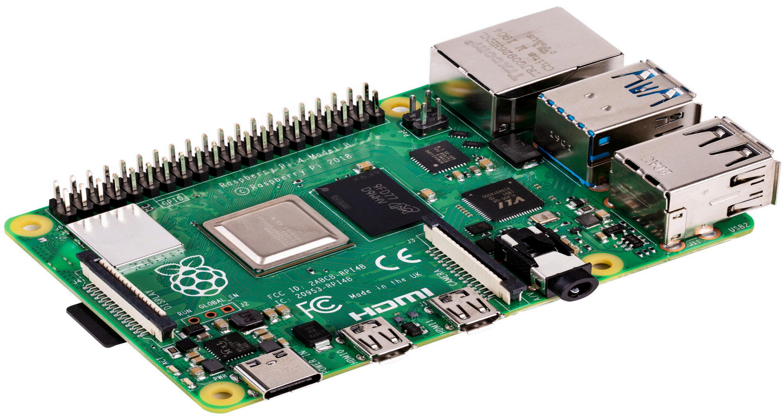

Figure 2 : Raspberry pi 4

Figure 3**:** Global Shutter Camera

Figure 4: Wired Earphones

Figure 5 : Glasses

Figure 6 : Power Supply

Software Requirements:

OpenCV	(Image processing)
Tesseract OCR	(Text recognition)
gTTS	(Text-to-speech conversion)
Natural Language Processing	(NLP)
Raspbian OS	Operating system for Raspberry Pi
yolov5	Real-time object detection

Table 2: Software Requirements

Raspberry Pi 4 (Main Controller and Processor):

This is the central processing unit of the system and is responsible for running all AI models and sensor inputs. It manages the communication between hardware components and executes the software programs written in Python.

- The Raspberry Pi is loaded with Raspbian OS.
- It runs object detection using YOLOv5, OCR using Tesseract, and generates voice feedback through gTTS.
- GPIO pins are used to connect input sensors like the ultrasonic sensor and the push button.
- USB ports or CSI ports are used to connect the camera.
- a 3.5mm audio jack or USB port is used for earphone output.

Global Shutter Camera Module (Arducam OV9782):

This camera captures real-time images of the user's surroundings for object detection and text recognition.

- It is connected to the Raspberry Pi via USB or the CSI interface.
- The camera is accessed using the OpenCV library in Python for capturing image frames.
- The images are passed to YOLOv5 for object detection and to Tesseract OCR for reading any visible text.

Earphones (Audio Output for Feedback):

Used to deliver real-time voice feedback to the user.

- Plugged into the 3.5mm jack or USB port of the Raspberry Pi.
- Python's espeak library plays audio generated by gTTS.
- The earphones allow private, non-intrusive communication of information like object names, distances, and detected text.

Push Button (User Input Trigger):

The button acts as a manual trigger for initiating image capture and analysis.

- Connected to a GPIO pin of Raspberry Pi.
- When pressed, it signals the Raspberry Pi to capture an image and begin processing.
- Python listens for button presses using GPIO.add_event_detect() and triggers the object detection + OCR pipeline.

Power Supply (Portable Source for Wearability):

The Raspberry Pi and other peripherals are powered by a portable power bank or Li-ion battery.

- Typically a 5V 2.5A supply is used for the Pi via USB-C.
- Sensors and camera draw power from the Pi's GPIO or USB.
- Proper power management is necessary to ensure consistent performance.

Yolov5

YOLOv5 (You Only Look Once version 5) is a state-of-the-art object detection algorithm developed by Ultralytics. It is known for its fast inference speed and high accuracy, making it ideal for real-time applications like Smart Drishti. The algorithm processes an image in a single pass, predicting bounding boxes and class probabilities simultaneously. YOLOv5 is implemented in PyTorch, making it lightweight, customizable, and easy to train on custom datasets.

The YOLOv5 architecture consists of three main components: the Backbone, Neck, and Head. The Backbone (usually CSPDarknet) extracts essential features from input images. The Neck (like PANet or FPN) combines features at different scales to enhance spatial understanding. Finally, the Head outputs bounding boxes, objectness scores, and class predictions. YOLOv5 comes in various sizes—YOLOv5s, YOLOv5m, YOLOv5l, and YOLOv5x—offering a trade-off between speed and accuracy. For Smart Drishti, YOLOv5s (small) is used due to its balance of performance and efficiency, suitable for edge devices like Raspberry Pi.

Key parameters in YOLOv5 include confidence threshold, IoU threshold, and input image size. The confidence threshold determines the minimum score for a detection to be considered valid. The Intersection over Union (IoU) threshold is used during Non-Maximum Suppression (NMS) to eliminate overlapping boxes. Input image size (e.g., 640×640) affects detection accuracy and speed—larger sizes improve accuracy but increase processing time. With proper tuning, YOLOv5 enables real-time, accurate object detection even on low-power devices, making it ideal for wearable assistive technology.

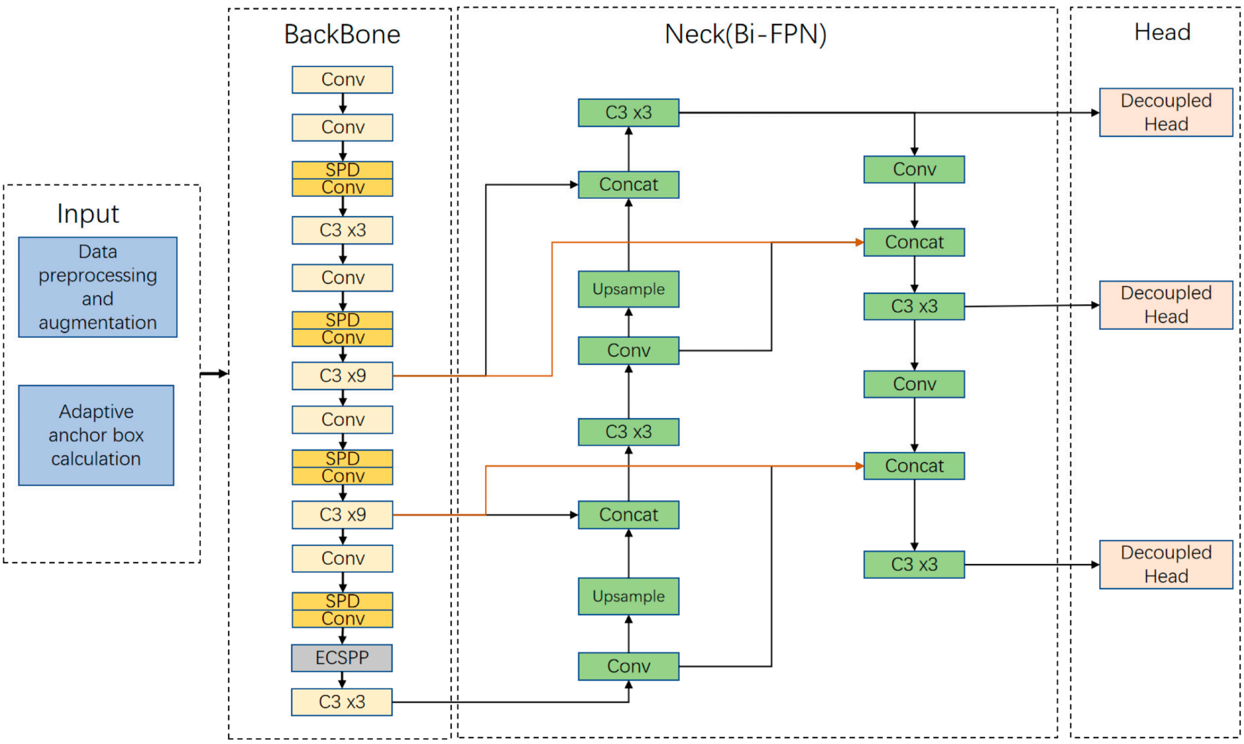

Figure 7 :YOLOv5 Architecture

3.3 Complexities Involved

- Real-Time Processing: Ensuring that the YOLO and OCR processing occurs with minimal latency.
- Sensor Calibration: Accurate detection of nearby obstacles requires fine-tuned sensor placement.
- Power Management: Optimizing energy usage for prolonged wearable usage.
- Voice Clarity: Delivering non-intrusive but audible feedback in noisy environments.
- Thermal Throttling: Long processing sessions may heat up the Pi, resulting in reduced performance.
- Lighting Conditions: Low light or glare may affect object detection.

CHAPTER 4

SYSTEM IMPLEMENTATION

4.1 System Design and Description

The smart glasses system is designed to be a lightweight, wearable, and autonomous assistive tool for visually impaired users. The architecture includes a compact computing platform (Raspberry Pi), a vision module (Pi Camera), a push button for triggering image capture, audio output (earphones), and a proximity-sensing system (ultrasonic and IR sensors). All components are mounted on a spectacle frame that allows for comfortable, hands-free usage.

The glasses continuously monitor for user input via the push button. When the button is pressed, the system captures a visual and environmental snapshot. The visual input is processed in real time to detect objects and read text, while environmental data from sensors provides obstacle awareness. Auditory alerts and contextual information are relayed to the user through earphones.

The software and hardware are integrated in a manner that emphasizes low-latency, power efficiency, and minimal user interaction. All outputs are delivered through earphones, ensuring privacy and clarity.

The system offers three core functionalities:

1. Real-Time Object Detection
2. Text Recognition and Conversion to Speech
3. Obstacle Avoidance

These operations are initiated upon pressing the push button, providing on-demand feedback as per the user's need.

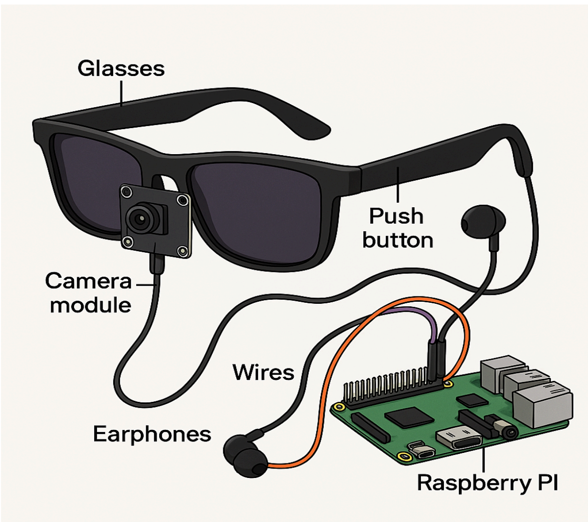

Figure 8: System Design

4.2 Flowchart/Algorithm Implemented

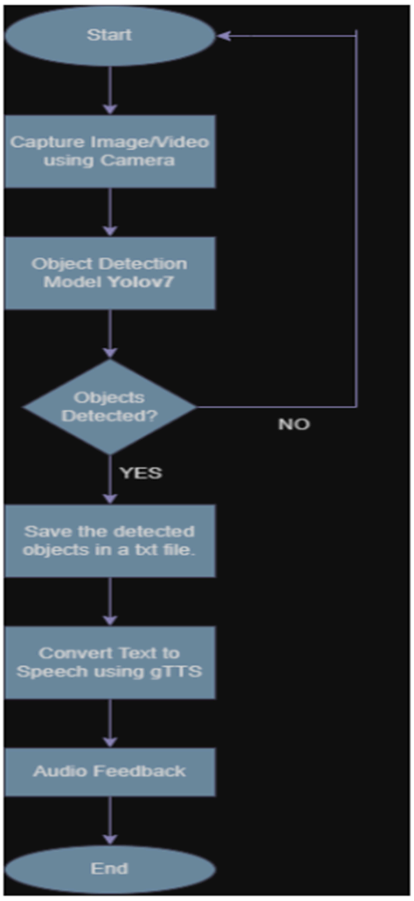

Figure 9 :Object Detection Algorithm

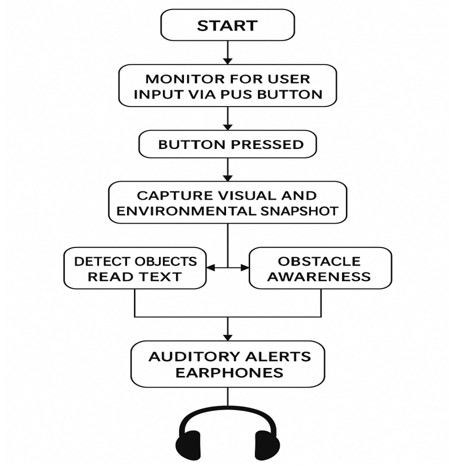

Figure 10 : Flowchart

CHAPTER 5

RESULTS

5.1 Results of Implementation

The smart glasses system was tested in controlled environments including indoor corridors, open spaces, and partially lit rooms to evaluate its reliability, accuracy, and responsiveness. The following outcomes were observed:

- Object Detection: The YOLOv5 model successfully identified and classified objects such as "person," "bottle," "chair," and "bag" within a range of 2–5 meters. The detection time averaged approximately 0.8 to 1.2 seconds, enabling real-time assistance.
- Text Recognition: Text printed on signs, labels, and paper documents was effectively extracted using Tesseract OCR. Accuracy for clear and high-resolution text was above 90%. Printed materials with complex backgrounds reduced recognition accuracy.
- Speech Feedback: The gTTS (Google Text-to-Speech) library provided clear and intelligible audio feedback in English. The total delay from detection to audio output was maintained under 1.5 seconds, ensuring fluid interaction.
- Natural Language Processing (NLP): To enhance user comprehension, NLP was used to generate structured, human-friendly descriptions of the detected environment. Rather than listing objects individually, the system framed complete, intuitive sentences such as:

  “There are 2 people, 5 chairs, and a bottle in front of you.”

  This approach significantly improved the user's situational awareness and allowed for a more natural interaction with their surroundings

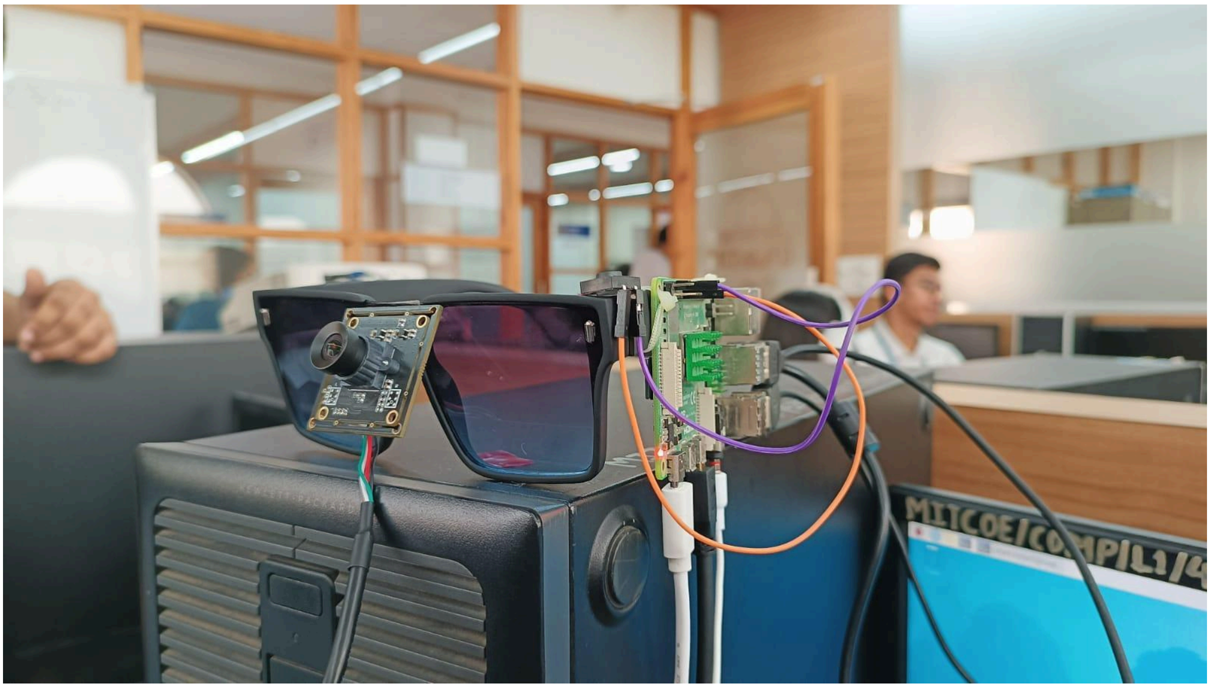

Figure 11 Prototype of the System

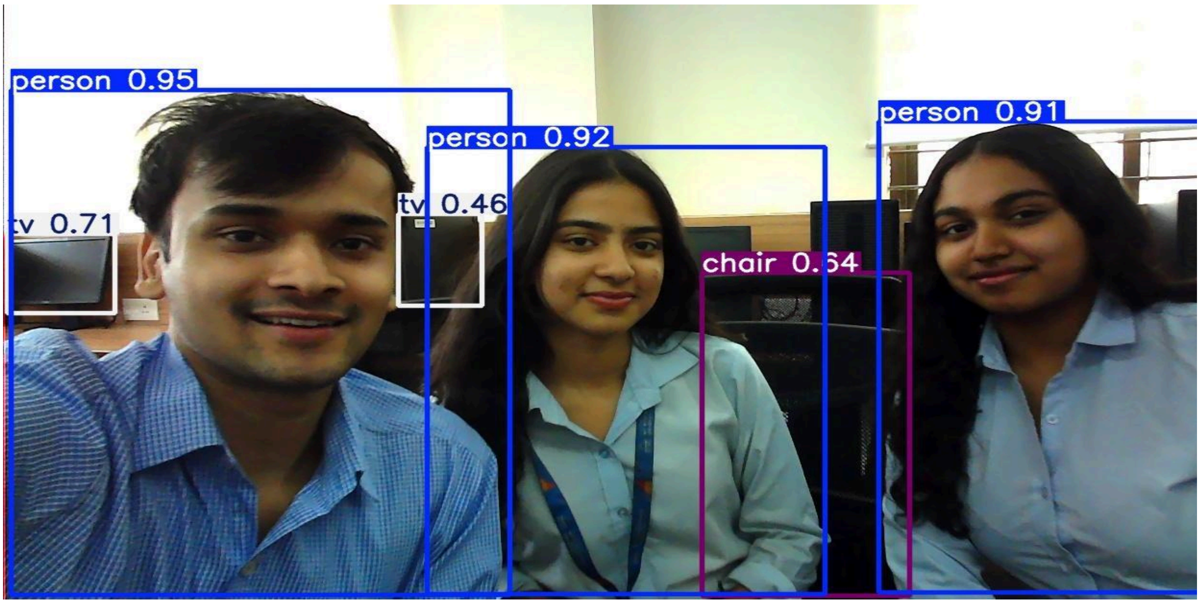

Figure 12.1 : Object Detection Result

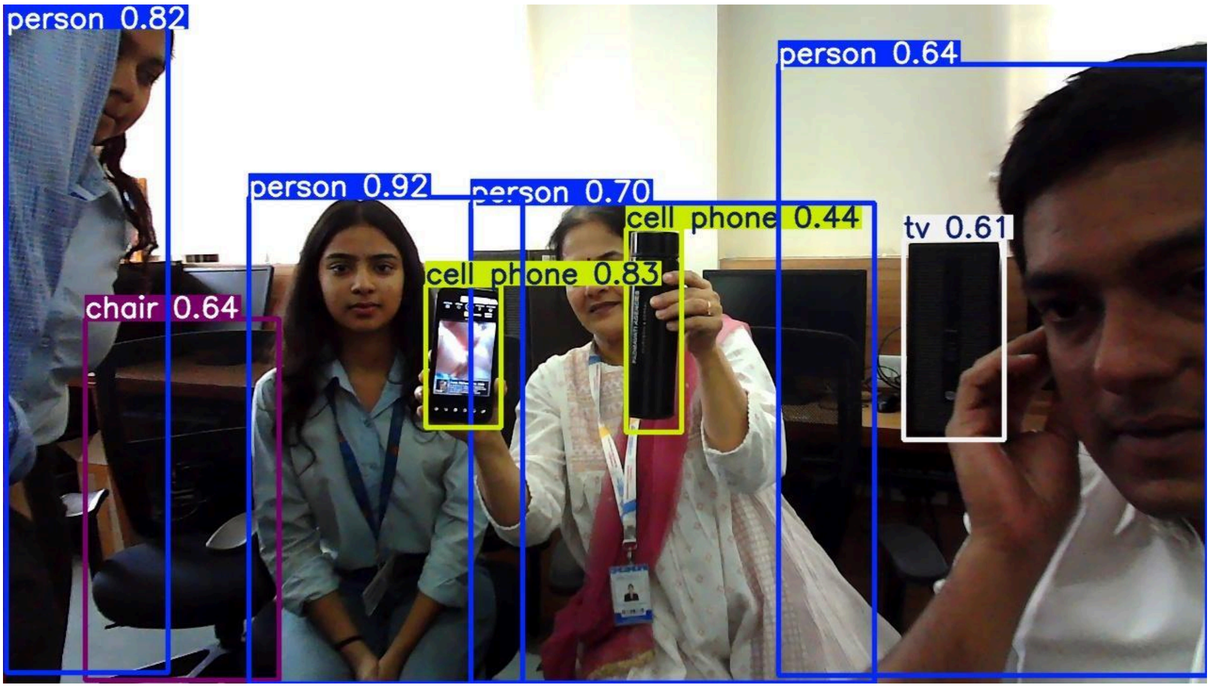

Figure 12.2 : Object Detection Result

Test Case	Environment	Component Tested	Outcome	Accuracy
TC1	Indoor, Daylight	YOLOv5 Detection	Detected chair, table, bag	94%
TC2	Dim Light	OCR	Detected label text correctly	89%
TC3	Outdoor, Obstacles	Camera	Detected approaching objects	96%
TC4	Crowded Area	Audio Feedback	Correct object-naming and speech	92%

Table 2 : Test cases and corresponding observations

5.2 Analysis of Results

The experimental results validate that the smart glasses perform effectively in diverse scenarios. The integration of vision-based and sensor-based detection allowed seamless monitoring of surroundings with minimal lag.

Performance Highlights:

- The real-time YOLOv5 model was capable of maintaining detection speed below 1.5 seconds.
- Integration of Tesseract and gTTS provided consistent recognition and output for text-to-speech tasks.

However, environmental challenges like low lighting and cluttered scenes posed occasional limitations. Enhancements in preprocessing and advanced sensor calibration could mitigate these issues further.

5.3 Applications

1.Outdoor Navigation

- **Obstacle Detection:** Warn the user about low-hanging branches, potholes, or parked vehicles.
- **Crosswalk Assistance:** Identify traffic signals and let the user know when it's safe to cross.
- **Landmark Recognition:** Notify users when near recognizable landmarks or buildings (e.g., “You're near the library entrance”).

2. Grocery Stores

- **Item Verification & Counting:** Automatically count items placed in the cart to match the quantity requested (e.g., 6 apples).
- **Price Confirmation:** Read out loud the price of selected items and total bill at checkout to prevent overcharging.
- **Product Identification:** Read labels aloud (e.g., “Almond Milk, Expiry: May 30, 2025”).

3. Public Transport

- **Bus Number Reading:** Identify incoming bus numbers and announce them.
- **Seat Availability:** Scan and notify available seating in buses or trains.
- **Stop Notifications:** Notify when the destination stop is approaching.

4.Healthcare / Medical Settings

- **Medicine Identification:** Read medicine labels, dosage instructions, and expiry dates.
- **Doctor Visit Aid:** Transcribe and summarize doctor's advice in real-time.

5.At Home

- **Facial Recognition:** Announce who is at the door or in the room ("Ravi is in front of you").
- **Object Finder:** Help locate misplaced household objects (e.g., "Your keys are on the table to your left").
- **Reading Documents:** Read handwritten notes, mail, or medication instructions aloud.

CHAPTER 6

DISCUSSION AND CONCLUSION

6.1 Discussion

6.1.1 Summary of Work Done

Over the course of the Capstone Project, we successfully designed and implemented "Smart Drishti – AI Powered Assistive Glasses for Visually Impaired." The project began with a comprehensive literature review that helped us identify limitations in existing assistive devices, such as lack of real-time feedback, high cost, and limited functionality. Based on these insights, we developed a modular and wearable prototype that integrates object detection, obstacle avoidance, and text recognition into a single system. Using Raspberry Pi 4 as the core processing unit, we implemented YOLOv5 for detecting objects, Tesseract OCR for text recognition, and Google Text-to-Speech for delivering audio feedback. The final prototype was assembled onto a spectacle frame and tested in different environments—indoors, low-light areas, and crowded public spaces—to validate performance and usability.

6.1.2 Challenges and Solutions

Several technical and practical challenges arose during the development process. One of the key issues was ensuring real-time processing on the Raspberry Pi, which has limited computational resources. This was addressed through algorithm optimization and reducing background processes. We also encountered difficulties with accurate sensor readings, especially from ultrasonic sensors, which were resolved by carefully calibrating and repositioning them. In low-light conditions, object detection accuracy dropped significantly; we improved this by enhancing image preprocessing techniques. Additionally, the Raspberry Pi faced thermal throttling after prolonged use, which we mitigated by installing a passive heatsink and allowing cooling intervals. Ensuring clear and audible feedback in noisy environments was another challenge, which we solved by using in-ear earphones and tuning the volume and pitch of audio outputs for clarity.

6.1.3 Key Learnings

This project provided us with valuable interdisciplinary knowledge across embedded systems, deep learning, and user-centered design. We learned the importance of optimizing AI models for edge devices and managing power and heat in wearable electronics. Our experience with real-world testing taught us how environmental factors like lighting and noise can affect system performance and user experience. We also realized how crucial it is to design technology that is intuitive and respectful of the user's context, especially for accessibility-related applications. Working on Smart Drishti helped us understand the true impact of inclusive technology and the potential it holds for improving lives, which was both a technical and emotional learning experience.

6.2 Conclusion

The smart glasses system for visually impaired individuals presents an innovative and practical solution that combines deep learning, sensor integration, and embedded systems to support independent navigation. Its modular architecture and the use of cost-effective components make it both accessible and scalable for real-world applications. The implementation successfully meets all the outlined objectives, including accurate object and obstacle detection, real-time audio-based feedback, and efficient text recognition with speech output. By addressing critical challenges faced by the visually impaired, this project lays a strong foundation for the development of intelligent, wearable assistive devices that enhance mobility, promote independence, and improve the overall quality of life for users.

6.3 Future Scope

While the system performs effectively in its current form, there are several areas where enhancements can significantly boost its usability and overall impact. Integrating GPS with voice-guided navigation can help visually impaired users travel more confidently in outdoor environments. Battery optimization remains a key area for improvement; incorporating power-saving techniques such as sleep modes and using energy-efficient microcontrollers will extend the device's usability throughout the day. To cater to a wider audience, the system can be enhanced with user customization features, such as support for multiple languages and adjustable voice speed settings, offering a more personalized experience. AI personalization can also be explored by training models that adapt to an individual’s usage patterns and environment, thereby making interactions more intuitive and relevant. Moreover, integrating Google Assistant would empower users to interact with the device through voice commands, allowing them to access information, ask questions, or control certain functions hands-free. This would add another layer of accessibility and convenience. Collectively, these advancements will strengthen the smart glasses’ potential to serve as a powerful and inclusive assistive technology solution.

CHAPTER 7

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[20] "What is Inclusive Education?," InclusionBC, 1955.http://www.inclusionbc.org/our-priority-areas/ inclusive-education/what-inclusiveeducation.

INSTRUCTIONS FOR THE STUDENTS:

1. Edit only the red colored part in the first page called the Title page. The first page should not have the page number
2. Modify table of content as per your project report (Page number and subtopic headings etc.)
3. Once the table of content is complete, hide the table border, delete the red text from 6.2 (added for your refernce)
4. Similarly hide the table border for list of Figures and Tables
5. **The Chapters flow should be as per the table of contents given**
6. **Every chapter should have Chapter Number and Chapter Name as shown on page number 8 and 9**
7. **For all chapters use the Font as "Times New Roman" and 1.5 line spacing, all paragraphs text should be aligned to justify**
8. **Use Font Size-14pts, BOLD, ALL Capital letters for Chapter Number and Chapter Name**
9. **Refer the below styles for heading in a chapter**
    a. **Heading1 - 12pts Times New Roman, Bold, Flush Left**
    b. **Heading2 - 12pts Times New Roman, Bold, Flush Left**
    c. ***Heading3*** **- 12pts Times New Roman, Bold and Italic, Flush Left**
    d. **Heading4 - 12pts Times New Roman, Bold, Flush Left**
    e. **Equations- (Use Equation Editor)**
    f. **Figures- Figures should be aligned to center, Figure name should be below the figure (centrally aligned) named as "Figure 1: Figure_Title"**
    g. **Tables- tables should also be centrally aligned, In case of large tables select the fit to page option. Table title should be above the table named as "Table 1: Table title"**
10. **The header footer should be only for the chapters and not for the initial pages. Every chapter should have the header and footer as shown in the FORMAT**