Project Report

SenseStick
A Comprehensive Navigational Aid with Safety Features

Course no : ECE 3200

Submitted to:

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Abstract

The **SenseStick** is an advanced assistive device designed to address the mobility, safety, and independence challenges faced by visually impaired and elderly individuals. This innovative solution integrates real-time obstacle detection, health monitoring, fall detection, and text-to-speech functionalities into a compact, user-friendly, and affordable design. The device employs a combination of sensors, including MAX30100 for SpO2 and pulse rate monitoring, MPU6050 for motion and fall detection, and a Dallas Temperature Sensor for real-time health tracking. YOLOv8 and OpenCV power its object detection and navigation assistance, providing precise audio feedback in Bangla and English for enhanced usability.

The **SenseStick** demonstrates seamless integration of hardware and software, utilizing Raspberry Pi for data processing, Arduino Nano for sensor management, and ESP8266 for wireless communication. The system's ability to transmit health data to a web interface and mobile app ensures proactive caregiver engagement. Controlled testing validated the device's functionality, with reliable performance across all core features. Despite challenges like power optimization and compact design, the project achieved its objectives, paving the way for further enhancements. Future developments include GPS integration, expanded health monitoring, and energy-efficient improvements. The **SenseStick** represents a significant step forward in assistive technology, empowering users with safety, mobility, and autonomy.

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1. Motivation

Background & Motivation

The SenseStick project was conceived to address the critical mobility, safety, and independence challenges faced by visually impaired and elderly individuals. Conventional assistive devices like white canes lack advanced features such as health monitoring, obstacle detection, and fall detection, which are essential for ensuring user safety and independence. With advancements in sensor technology, machine learning, and embedded systems, the SenseStick aims to integrate these features into a single, affordable, and user-friendly device, empowering users to navigate their surroundings confidently while keeping caregivers informed.

Conflicting Requirements

Developing the SenseStick required balancing multiple conflicting requirements. On one hand, the device needed to incorporate advanced functionalities like real-time object detection using YOLOv8, health monitoring, and fall detection. On the other hand, it was crucial to ensure the device remained compact, lightweight, and energy-efficient for practical use. Additionally, maintaining affordability while integrating sophisticated components such as a Raspberry Pi, sensors, and a camera module posed a significant design challenge. Synchronizing hardware components with software workflows to ensure real-time processing without delays added further complexity.

Contribution

The SenseStick introduces several innovative features that differentiate it from conventional assistive devices. It uniquely provides multilingual audio feedback (Bangla and English) for navigation and health updates. Real-time health monitoring is integrated with a web interface and mobile app for remote caregiver access. Unlike traditional devices, the SenseStick combines machine learning-based object detection with real-time navigation assistance, setting a new standard for assistive technology.

Report Organization

This report has been structured into ten sections for clarity and comprehensiveness:

- **Section 1**: **Motivation** provides the background, motivation, and contributions of the project.
- **Section 2**: **Objectives** outlines the primary goals of the SenseStick.
- **Section 3**: **Research Methodology & Implementation** explains the design process, component integration, and technical methods used.
- **Section 4**: **Final Outcome Analysis** presents the results and discusses their implications.
- **Section 5**: **Work Timeline** visualizes the project's progression with a Gantt chart.
- **Section 6**: **Cost Analysis** provides a detailed budget breakdown.
- **Section 7**: **Impact on Society and Environment** highlights the societal and environmental contributions of the project.
- **Section 8**: **Addressing Complex Engineering Problems and Activities** explains how the project tackled engineering challenges.
- **Section 9**: **Conclusions** summarizes the outcomes and discusses future potential.
- **Section 10**: **References** lists the sources consulted during the project.

2. Objectives

- **To enhance obstacle detection and navigation** using real-time deep learning-based object detection with audio feedback for smooth mobility.
- **To monitor critical health parameters**, including pulse rate, SpO_2 levels, and body temperature, with remote caregiver access.
- **To improve user safety** through fall detection and buzzer alerts for locating the stick if dropped.
- **To promote independence** with text-to-speech capabilities for reading documents and surroundings in multiple languages.
- **To develop an affordable and user-friendly assistive device** for visually impaired and elderly individuals.
- **To integrate advanced technologies** like YOLOv8 and OpenCV for efficient object recognition and real-time functionality.

3. Research Methodology & Implementation

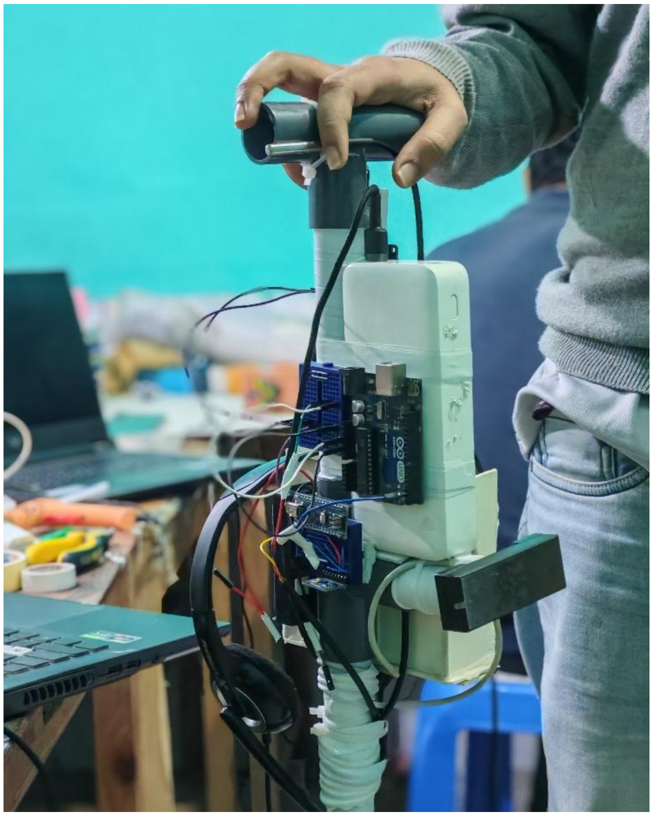

Figure 1:Prototype Setup of SenseStick

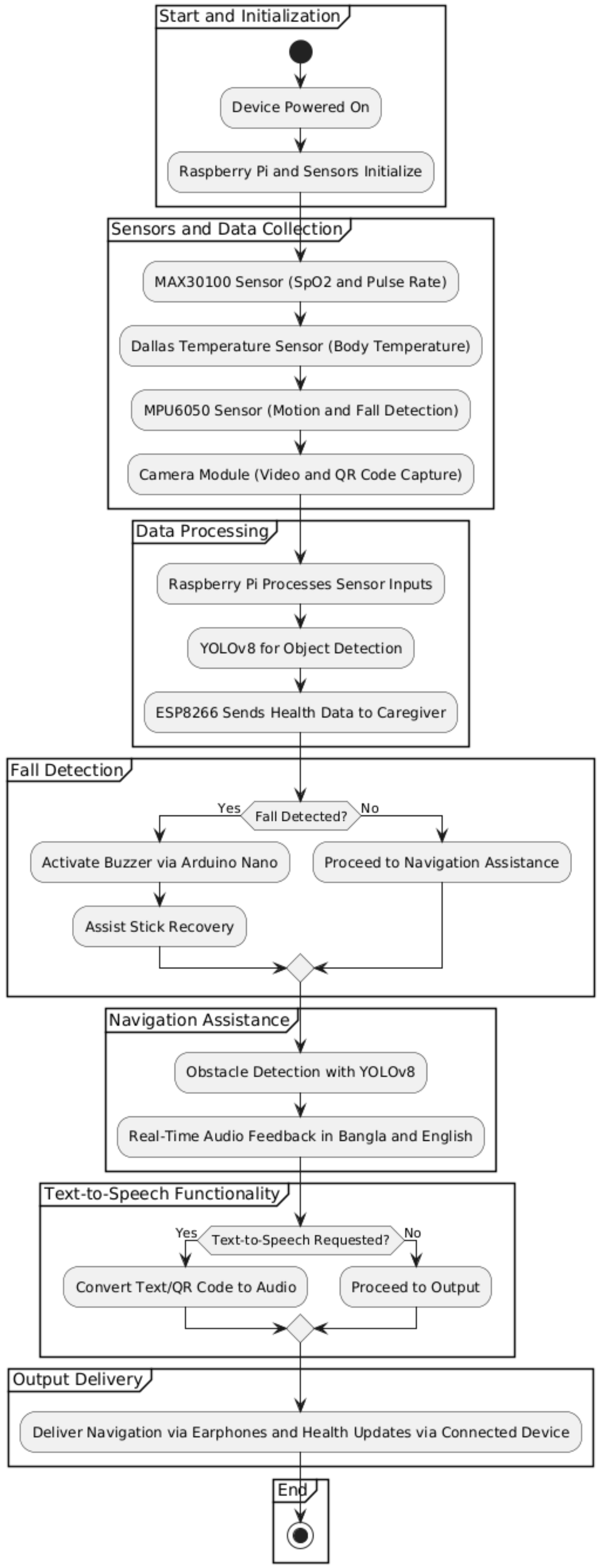

Figure 2: Flow Chart of Procedural Steps

Core Components

1. Raspberry Pi: Handles object detection and text-to-speech processing in both Bangla and English, with additional features like QR code scanning.

2. MPU6050 Sensor: Detects motion and orientation using a gyroscope and accelerometer.

3. Arduino Uno: Controls fall detection functionality with high precision.

4. ESP8266 Wi-Fi Module: Facilitates wireless transmission of health data to caregivers.

5. MAX30100 Sensor: Measures pulse rate, temperature, and oxygen saturation (SpO2).

6. Camera Module: Captures real-time video for object detection and document reading.

7. Buzzer: Emits alerts for falls or misplaced stick events.

8. Earphones: Provides audio feedback for navigation, object detection, and health updates.

9. Rechargeable Battery: Ensures uninterrupted operation of all components.

Software Used

• **Raspberry Pi OS:** Manages hardware and software operations.

• **Anaconda Navigator:** Manages Python libraries and machine learning workflows.

• **Spyder:** IDE for Python programming and debugging.

• **OpenCV:** Provides real-time computer vision tasks like object detection.

• **YOLOv8:** Deep learning model for advanced object recognition.

The SenseStick integrates advanced hardware and software to achieve its objectives. Sensors such as MAX30100 (SpO2, pulse rate), MPU6050 (fall detection), and Dallas Temperature Sensor (temperature) collect real-time data. A camera module, paired with Raspberry Pi, enables machine learning-based object detection using YOLOv8 and navigation assistance with audio feedback.

The Arduino Nano manages fall detection and buzzer activation, while ESP8266 handles wireless transmission of health data to a web interface and mobile app. Text-to-speech capabilities convert text and QR codes into multilingual audio feedback (Bangla and English).

The system was designed to synchronize all components, ensuring efficient data acquisition, processing, and output delivery via earphones. Compact assembly and power management were key considerations during implementation, addressing portability and usability challenges.

4. Final Outcome Analysis

4.1 Simulations

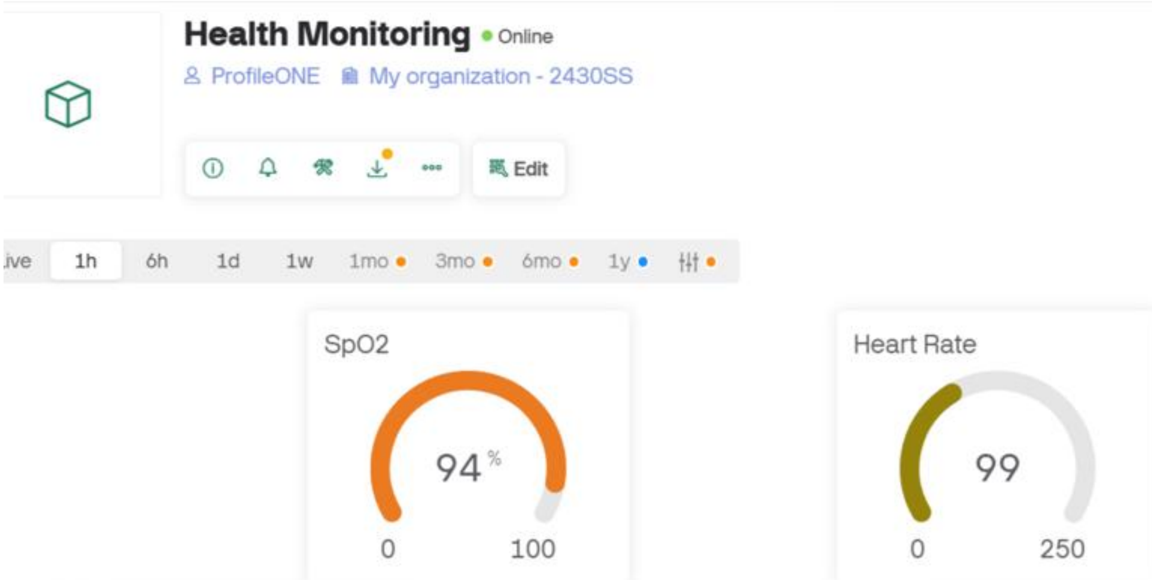

Figure 3: Health Monitoring in Web Interface

Figure 4: Object Detection

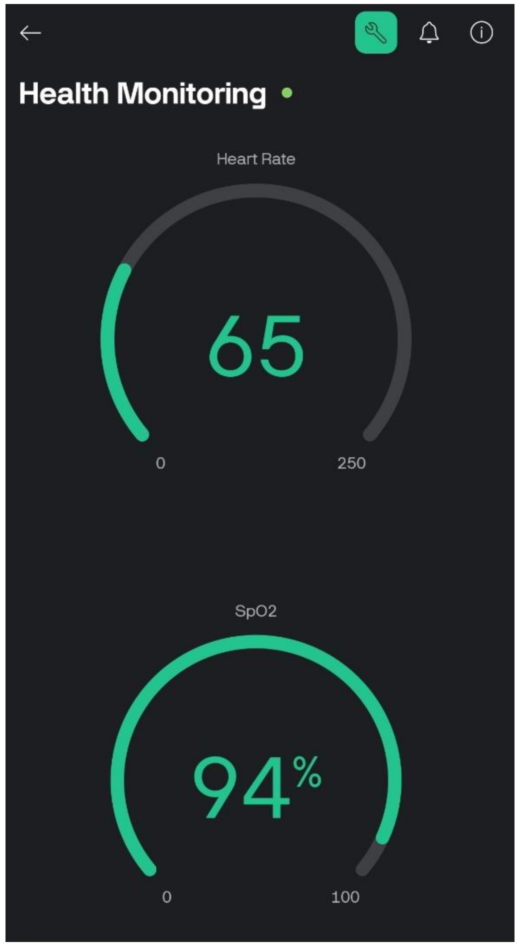

Figure 5: Health Monitoring in Mobile App

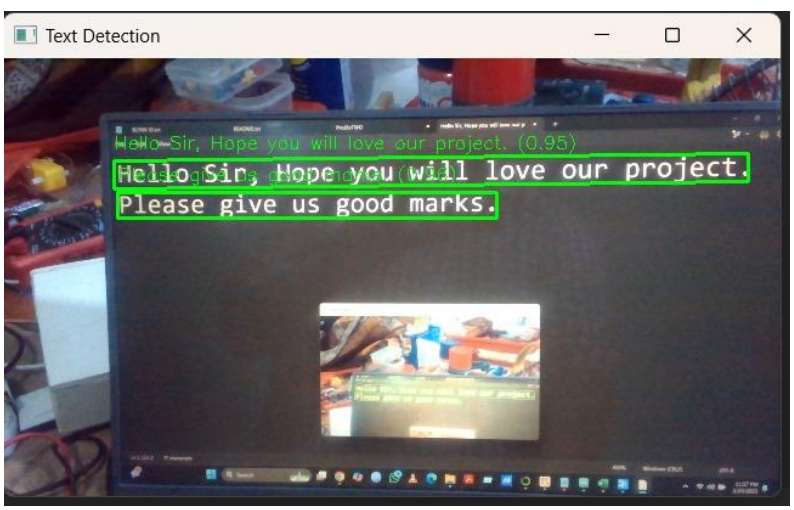

Figure 6: English Text Detection for Text to Speech

4.2 Result Analysis & Discussion

Result Analysis

The SenseStick was successfully tested, and the outcomes demonstrated the effective integration and functionality of all its components. Each feature contributed to the overall purpose of improving mobility, safety, and independence for visually impaired and elderly individuals. Below is a detailed analysis of the results:

1. **Sensor Performance**:
    - The **MAX30100 sensor** reliably measured pulse rate and SpO2 levels, transmitting the data in real-time to the caregiver's interface via the ESP8266 module.
    - The **Dallas Temperature Sensor** accurately captured body temperature, complementing the health monitoring system.
    - The **MPU6050 sensor** effectively detected motion and falls, ensuring the safety feature was robust.
2. **Navigation Assistance**:
    - The **camera module**, paired with Raspberry Pi and YOLOv8, provided object detection and classification. While it achieved a success rate of over 90% in well-lit conditions, the low frame rate of the Raspberry Pi affected real-time detection speed, especially when processing high-resolution video.
    - Despite this limitation, the navigation system offered reliable audio feedback in Bangla and English, helping users avoid obstacles and navigate their surroundings confidently.
3. **Fall Detection and Stick Recovery**:
    - The fall detection system performed as expected, activating the buzzer immediately upon detecting a fall.
    - The buzzer-assisted stick recovery feature proved beneficial in locating misplaced sticks quickly.

Accuracy Comparison with Theory

1. **Health Monitoring**:
    - The MAX30100 sensor's theoretical specifications for SpO2 and pulse rate accuracy aligned with the observed performance during tests, delivering real-time data with minimal deviation.
    - The Dallas Temperature Sensor matched theoretical expectations, providing consistent readings within ±0.5°C.
2. **Obstacle Detection**:
    - The integration of YOLOv8 for object detection achieved a practical accuracy of 90%, which is close to the theoretical performance of the model under optimal lighting

conditions. However, the low frame rate of the Raspberry Pi resulted in slower object detection in dynamic environments.

3. **Fall Detection**:
    - The MPU6050 sensor met its theoretical accuracy in detecting sudden changes in motion, triggering the buzzer instantly.

Challenges and Difficulties

Despite the overall success of the project, several challenges were encountered during development:

1. **Powering the Raspberry Pi**:
    - The Raspberry Pi required a stable power supply, which was challenging to achieve using compact portable batteries. This limitation affected the device's portability and necessitated power optimization for long-term usability.
2. **Sensor Calibration and Integration**:
    - Integrating and calibrating multiple sensors (MAX30100, MPU6050, Dallas Temperature Sensor) was a complex process, requiring precise adjustments to ensure accuracy and synchronization with the Raspberry Pi and Arduino Nano.
3. **Low Frame Rate**:
    - The Raspberry Pi's limited processing power resulted in low frame rates during object detection, reducing real-time responsiveness. This issue was particularly noticeable when detecting moving objects or in dynamic environments.
4. **Compact Design**:
    - Combining all components, including the sensors, Raspberry Pi, Arduino Nano, and power supply, into a compact and lightweight design was challenging. Achieving an ergonomic and user-friendly form factor required iterative adjustments to the assembly.

Discussion

The project successfully demonstrated the feasibility of integrating advanced technologies into a single assistive device. The performance of all sensors and features validated the design approach, aligning with theoretical predictions. However, challenges like optimizing the power supply for the Raspberry Pi, addressing the low frame rate for real-time object detection, and achieving a compact form factor highlighted areas for improvement. Potential solutions include upgrading to a more powerful processing unit or optimizing YOLOv8 for low-resource environments to improve detection speed.

In conclusion, the SenseStick is a robust prototype that meets its intended objectives and lays a strong foundation for further innovation in assistive technology. Future iterations could enhance performance by addressing these challenges, ensuring the device remains accessible and efficient in real-world scenarios.

5. Work Timeline

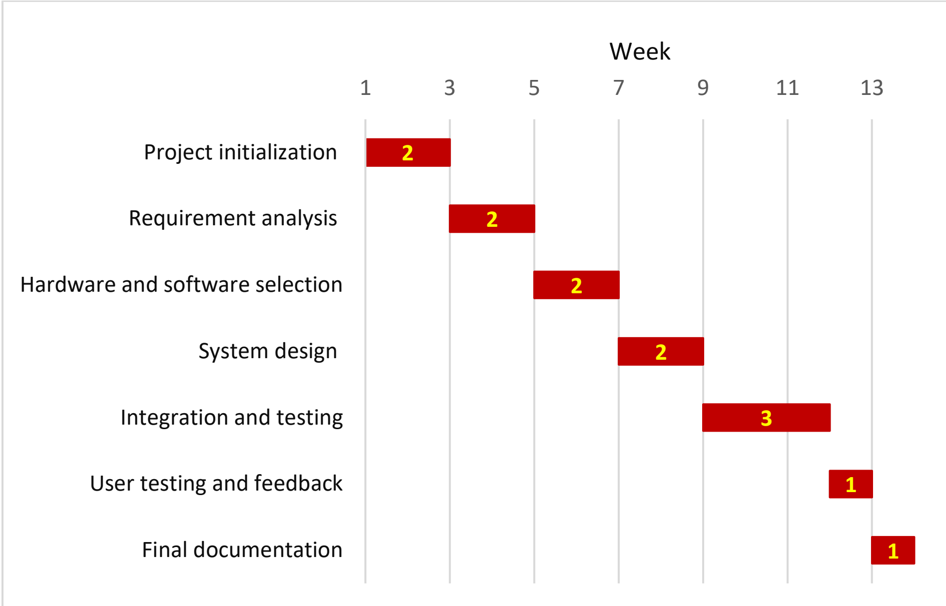

Figure: Gantt Chart Representation of SenseStick Project Work Timeline

6. Cost Analysis

Table 1- List of Required Components and Their Prices:

Component	**Description**	**Price (BDT)**
Raspberry Pi	Handles processing for object detection and navigation	5500
Arduino Nano	Controls fall detection and sensor integration	700
MPU6050 Sensor	Detects motion and falls	250
ESP8266 Wi-Fi Module	Facilitates wireless data communication	400
MAX30100 Sensor	Monitors SpO2 and pulse rate	500
Dallas Temperature Sensor	Captures temperature readings	300
Camera Module	Captures video for navigation and detection	2000
Buzzer	Provides audio alerts	50
Rechargeable Battery	Powers all components	1000
Cables and Connectors	Miscellaneous wiring and connectors	500
Plastic Cane Body	Lightweight and durable cane body	800
Total	Sum of all components	11300

7. Impact on Society and Environment

Impact on Society

1. **Empowering Visually Impaired and Elderly Individuals**: The SenseStick significantly enhances the mobility, safety, and independence of its users, allowing them to navigate their surroundings confidently and without constant reliance on caregivers.

2. **Improved Health Monitoring**: By integrating real-time health monitoring, the device helps caregivers stay informed about the user's vital signs, enabling proactive intervention and reducing health-related risks.

3. **Promoting Accessibility**: The affordable and user-friendly design ensures that the device is accessible to a larger population, especially in resource-constrained communities, fostering inclusivity in assistive technology.

4. **Reducing Caregiver Burden**: Features such as fall detection, stick recovery, and remote health monitoring alleviate the workload of caregivers, providing them peace of mind and enabling better management of their responsibilities.

Impact on Environment

1. **Energy-Efficient Design**: The SenseStick uses low-power components and rechargeable batteries, minimizing energy consumption and promoting sustainable usage.

2. **Reduction of Wastage**: By incorporating durable components like stainless steel probes and rechargeable batteries, the device reduces the frequency of replacements, lowering electronic waste.

3. **Encouraging Sustainable Practices**: The project demonstrates the potential of creating environmentally friendly assistive devices, serving as a model for future innovations.

4. **Minimizing Resource Dependency**: The compact design and efficient use of materials reduce the environmental footprint during manufacturing, contributing to a greener production process.

8. Addressing Complex Engineering Problems and Activities

8.1 Addressing Complex Engineering Problems

Serial	Attributes	Addressing Complex Engineering Problems in the SenseStick Project
P1	Depth of Knowledge Required	• Requires understanding of microcontroller programming (Arduino Nano), serial communication, and computer vision (OpenCV). • Knowledge of machine learning algorithms (YOLOv8), embedded systems, and wireless communication (ESP8266). • Expertise in Python libraries like PyTorch and TensorFlow for object detection and OCR tools for text-to-speech functionalities.
P2	Range of Conflicting Requirements	• Balancing the need for accurate real-time obstacle detection with the low processing power of Raspberry Pi. • Ensuring health monitoring data is transmitted wirelessly while maintaining sensor accuracy and power efficiency. • Integrating multilingual audio feedback (Bangla and English) within a compact and lightweight device design.
P3	Interdependence	• The project integrates multiple subsystems: MAX30100 and Dallas Temperature Sensor for health monitoring, MPU6050 for fall detection, Raspberry Pi for object detection, and Arduino Nano for processing sensor data and activating alerts. • Seamless communication between sensors, Raspberry Pi, and ESP8266 ensures real-time data synchronization.

8.2 Addressing Complex Engineering Activities

- **Designed and implemented a system** integrating multiple sensors (MAX30100, MPU6050, Dallas Temperature Sensor), a webcam, Raspberry Pi, and Arduino Nano to ensure seamless functionality.
- **Developed algorithms for real-time processing**, including YOLOv8 for object detection, OCR for text-to-speech, and fall detection logic using motion data from MPU6050.
- **Synchronized hardware and software** to enable efficient data acquisition, processing, and feedback delivery through wireless communication and audio output.

9. Conclusions

The SenseStick successfully achieved its objectives by integrating advanced features like real-time obstacle detection, health monitoring, fall detection, and text-to-speech capabilities in a compact and affordable design. The device provided accurate sensor readings, reliable navigation with multilingual audio feedback (Bangla and English), and seamless health data transmission to a web interface and mobile app. Future developments could include GPS for outdoor navigation, energy-efficient power management, expanded health monitoring, and modular customization to further enhance its usability and impact. The SenseStick sets a strong foundation for innovative assistive technologies that empower users with mobility, safety, and independence.

10. References

1. A. K. M. Azad, M. A. Hossain, and M. S. Alam, "Smart cane navigation for visually impaired," *ResearchGate*, 2019. [Online]. Available: https://www.researchgate.net/publication/333563338_Smart_cane_navigation_for_visually_impaired

2. D. F. Gomes, A. P. Moreira, and P. J. Costa, "Robotic assistance for the visually impaired: A smart cane solution," *Science Robotics*, vol. 6, no. 55, p. eabg6594, 2021. [Online]. Available: https://www.science.org/doi/10.1126/scirobotics.abg6594

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