SYSTEM PRODUCT DESIGN

PROJECT REPORT

SMART GLOVES FOR VISUALLY **IMPAIRED PERSONS**

TEAM – 19

INDIAN INSTITUTE OF INFORMATION TECHNOLOGY, DESIGN AND MANUFACTURING, KANCHEEPURAM

CHENNAI – 600127, TAMILNADU

This product was chosen as a result of the knowledge and skills we acquired in the previous semester. The concepts we learned, particularly in areas such as circuit design, embedded systems, and sensor integration, provided a strong foundation that guided our decision-making process. By applying this prior knowledge, we were able to identify a practical and innovative solution that aligns well with both our academic background and the project objectives.

MATRIX DISTRIBUTION

S.No.	Key Word	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	deg
1	Mobility		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	1
2	Education			1		1	1				1	1	1	1		1	1		1		1			1			12
3	Employement				1	1						1	1	1			1	1	1	1				1		1	10
4	Emotionals	1								1		1			1		1										5
5	Social Inclusion	1		1	1			1		1	1				1					1							8
6	Training	1						1				1	1			1	1										6
7	Rehabilitation				1	1			1					1		1	1										6
8	Misconceptions				1	1						1					1		1								5
9	Advocacy		1	1		1		1				1			1		1			1		1					9
10	Entrepreneur			1		1	1			1			1	1				1		1						1	8
11	Daily living					1			1	1			1	1					1								6
12	Independence											1					1										2
13	Social Influence							1	1			1	1					1									5
14	Psychological Support				1			1				1	1				1										5
15	Accessibility	1		1								1	1		1		1			1							7
16	Confidence	1	1	1	1	1	1	1		1	1	1	1		1												12
17	Public Infrasturucture	1	1	1			1					1	1		1	1	1			1							10
18	Discrimination		1	1	1	1		1	1			1	1	1	1	1	1										12
19	Caring Burden				1		1	1	1	1		1	1		1		1	1									10
20	Awareness		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		1		1			19
21	Health Care				1			1		1		1			1	1	1	1		1							9
22	Gender	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1		1					19
23	Technology	1	1	1		1	1	1		1	1	1	1	1		1		1			1	1					15
24	Age	1	1	1	1	1	1	1	1			1	1	1	1	1	1	1	1	1		1	1	1			20
25	Finance		1		1	1	1	1	1		1	1	1			1		1	1			1		1			14
	in degree	9	10	12	13	14	10	14	9	10	7	20	17	10	12	11	17	9	7	10	2	6	1	5	0	2	

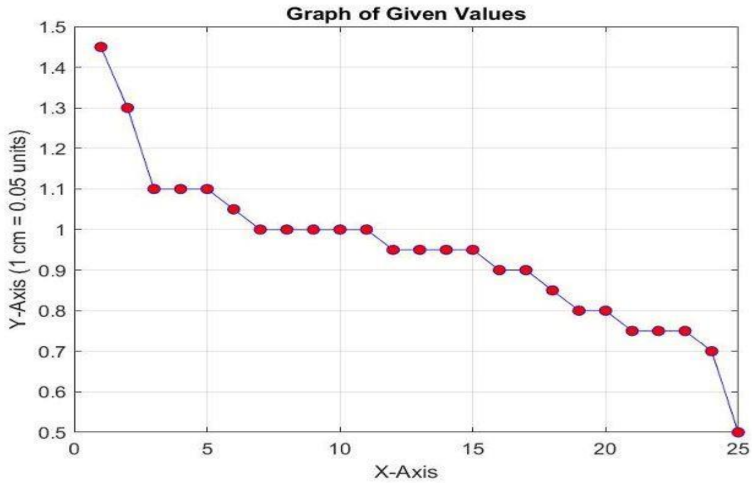
IN DEGREE

AND

OUT DEGREE

Key Word	in	out	Total Degree	Diff
Confidence	17	12	29	-5
Daily living	20	6	26	-14
Education	10	12	22	2
Employement	12	10	22	-2
Social Inclusion	14	8	22	-6
Awareness	2	19	21	-4
Rehabilitation	14	6	20	-8
Caring Burden	10	10	20	0
Gender	1	19	20	18
Technology	5	15	20	10
Age	0	20	20	20
Advocacy	10	9	19	-1
Independence	17	2	19	-15
Public Infrasturucture	9	10	19	1
Discrimination	7	12	19	5
Emotionals	13	5	18	-8
Accessibility	11	7	18	-4
Psychological Support	12	5	17	-7
Training	10	6	16	-4
Finance	2	14	16	12
Entrepreneur	7	8	15	1
Social Influence	10	5	15	-5
Health Care	6	9	15	3
Misconceptions	9	5	14	-4
Mobility	9	1	10	-8

DEGREE ANALYSIS

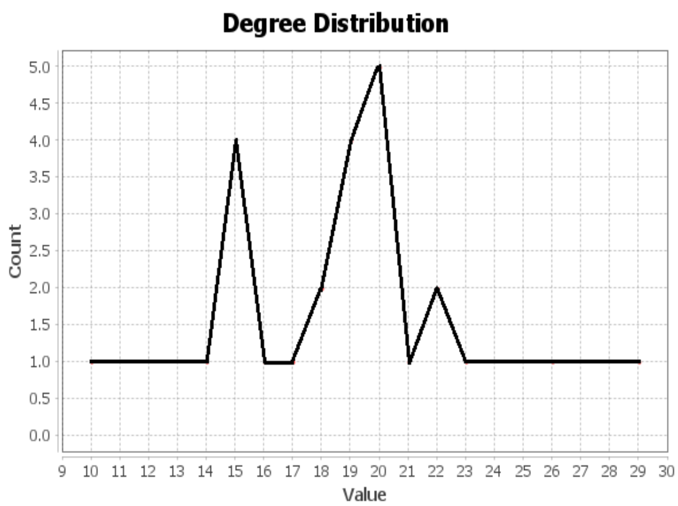


SNAC MATRIX

Stakeholders	Needs of stakeholders	Alterable for the system-in-focus	Constraints for the system-in-focus
S1. Blind peoples S2. Entrepreneur S3.N.G.O S4.Tech companies S5.Families and caregivers. S6.Government agencies	N1.1. Mobility N1.2.Employment N1.3. Advocacy N1.4. Technology N.2.1. Finance	A1.Education A2.Training A3. Accessibility A4.PublicInfrasturucture	C1.Age C2.Discrimination C3. Gender C4. Misconceptions
S7.Healthcare providers			

DEGREE OF DISTRIBUTION

GRAPH



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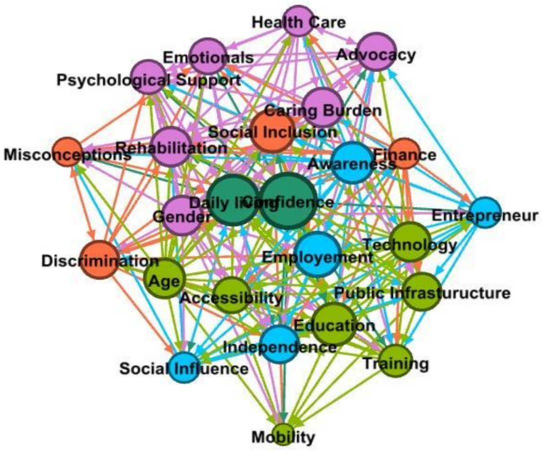
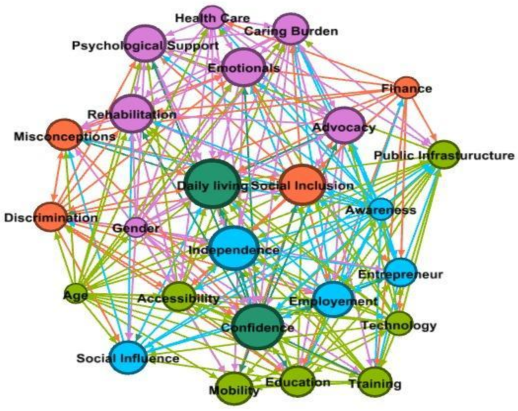
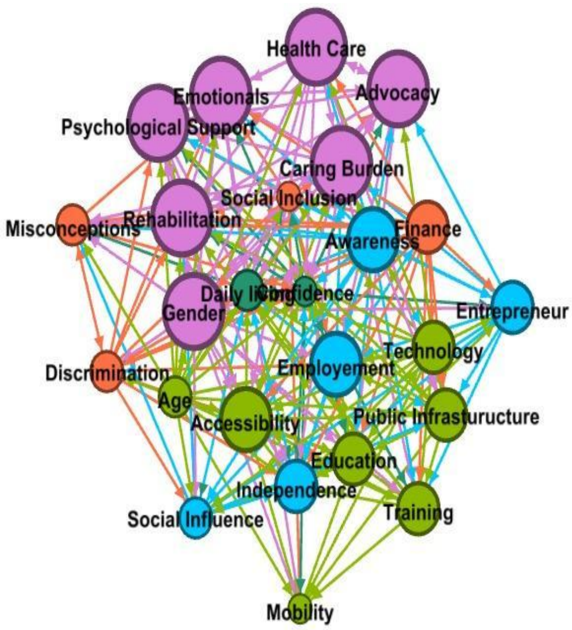


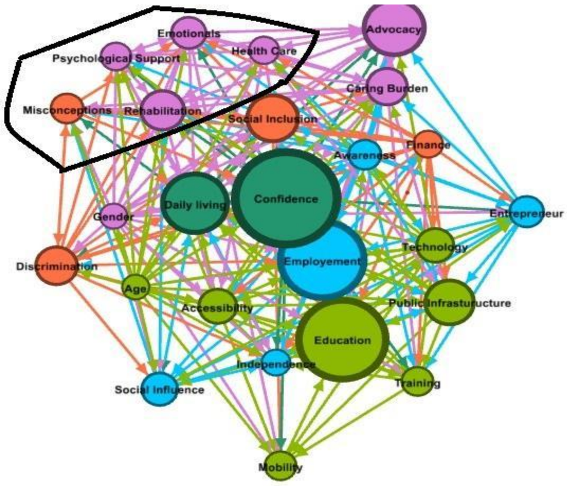
CENTRALITY



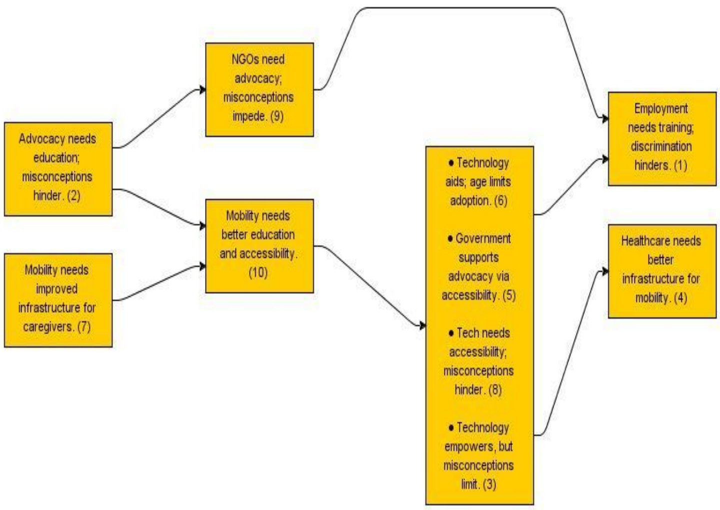
MODULARITY



CLUSTERING ANALYSIS: How closely nodes are connected in a graph.



HIERARCHY



Literature Survey

1. Literature Survey: Pothole Detection

1.1 Vision-Based Detection

Title: Automatic Pothole Detection Using Image Processing Techniques

Authors: Medapati et al. (2017)

Summary: Utilized a combination of edge detection and shape-based segmentation to identify potholes. They used grayscale conversion and Canny edge detection to highlight road damage.

Tools Used: OpenCV, Python

Limitations: Prone to false detection under poor lighting and shadow conditions.

1.2 Deep Learning Approach

Title: Pothole Detection and Localization Using Deep Convolutional Neural Networks

Authors: Maeda et al. (2018)

Summary: Used a CNN-based object detection model (YOLO) for real-time pothole detection with high accuracy.

Tools Used: YOLO, TensorFlow/Keras

Strengths: High detection accuracy, real-time capability.

Limitations: Requires large labeled datasets for training.

1.3 Sensor-Based Detection

Title: Smartphone-Based Pothole Detection System

Authors: Eriksson et al. (2008)

Summary: Used accelerometer data from smartphones placed in vehicles to detect sudden vertical movements indicating potholes.

Tools Used: Android sensors, machine learning

Strengths: Low cost and easy deployment.

Limitations: Not location-precise without GPS, sensitivity to driving style.

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2. Literature Survey: Money Detection

2.1 Traditional Image Processing

Title: Currency Recognition System using Image Processing

Authors: Nazari et al. (2014)

Summary: Detected currency notes using features like color, edge, and text through image processing techniques.

Tools Used: MATLAB, OpenCV

Limitations: Struggles with worn or folded notes.

2.2 Deep Learning-Based Detection

Title: Currency Recognition System using Convolutional Neural Networks

Authors: Singh and Banerjee (2020)

Summary: Implemented a CNN to classify images of currency into denominations. Achieved high accuracy on Indian and US currency datasets.

Tools Used: TensorFlow/Keras, CNN

Strengths: High robustness, even with complex backgrounds.

Limitations: Requires a large dataset with various note conditions.

2.3 Assistive Technologies

Title: Currency Recognition for Visually Impaired Using Mobile Camera

Authors: Al-Ghorani et al. (2016)

Summary: Mobile app with OCR and template matching to identify currency denomination and provide audio feedback.

Tools Used: Android, Tesseract OCR

Strengths: Real-world application, useful for blind people.

Limitations: May not work well with damaged notes or poor lighting.

OVERVIEW OF PROJECT:

This project involves the design and development of **smart gloves** tailored for **blind or visually impaired individuals**, incorporating **three core functionalities**:

1. **Pothole Detection:**
   Using a webcam and image processing algorithms running on a Raspberry Pi, the system detects potholes in the user's walking path. It provides real-time alerts through audio cues to ensure safer navigation.

2. **Currency Recognition:**
   The webcam also enables real-time currency recognition, helping the user identify currency denominations through voice output or haptic feedback. Deep learning models are used for accurate detection of various note types.

3. **Emergency Calling System:**
   Integrated with a **GSM SIM900A module**, the glove includes an **emergency switch**. When pressed, it automatically calls a predefined emergency contact for assistance, providing a lifeline in critical situations.

All AI models and logic run on the Raspberry Pi to eliminate dependency on internet Connectivity, ensuring offline reliability.

Objectives:

THESE ARE MAIN OBJECTIVES OF OUR PRODUCT

1. **Enhance Mobility for the Visually Impaired:**
   Provide safer navigation by detecting road hazards like potholes in real-time.

2. **Simplify Financial Transactions:**
   Assist users in identifying currency denominations quickly and accurately through a built-in recognition system.

3. **Enable Quick Emergency Response:**
   Implement an emergency calling system using a GSM module that can be activated instantly via a button press.

4. **Develop a Compact, Wearable, and User-Friendly Device:**
   Ensure the glove is lightweight, easy to wear, and provides intuitive feedback through voice, vibration, or buzzer alerts.

5. **Integrate AI and IoT Technologies:**
   Leverage Raspberry Pi, computer vision, and GSM communication for real-time processing and connectivity.

Methodology

The methodology followed for the development of **Smart Assistive Gloves for the Visually Impaired** involves a systematic approach combining hardware integration, software development, and real-time processing. The project can be divided into the following phases:

Major Components:

- Raspberry Pi 4/5
- USB Webcam
- GSM Module (SIM900A)
- Tactile Switch (Emergency Button)
- Battery Pack
- Bluetooth earphones /Audio Output (for feedback)
- Jumper wires

Hardware Integration

- Connected the webcam to the Raspberry Pi via USB.
- Interfaced the SIM800L GSM module using UART/GPIO pins with appropriate level shifters.
- Wired the emergency switch as an input to trigger GSM-based calls.
- Connected feedback output devices (speaker or vibration motor).
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Software Development

- **Operating System & Setup:** Installed Raspberry Pi OS with necessary libraries (OpenCV, TensorFlow, Serial communication tools).
- **Currency Detection Module:**
  - Captured note image using the webcam.
  - Applied image pre-processing.

- Passed the image to a trained CNN model.
- Output the denomination via audio feedback.

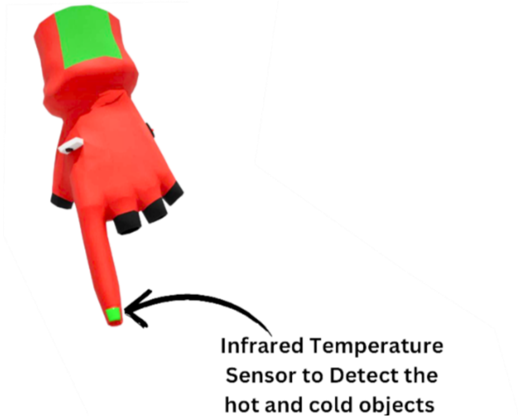
- **Pothole Detection Module:**
  - Captured frames in real-time images.
  - Used an object detection model to identify potholes.
  - Triggered if pothole was detected within danger range.
- **Emergency Calling Module:**
  - Monitored the emergency switch status continuously.

Triggered GSM call to a predefined contact on press.

Bill of Materials

s.no	Components	Prize
1	Respberry pi	₹ 8,338.00
2	Camera module	₹ 2,968.00
3	magnets	₹ 299.00
4	Lithium Batteries	₹ 798.00
5	Gsm Module	₹ 725.00
6	Glove	₹ 189.00
7	DC-DC booster	₹ 149.00
8	BSM Module	₹ 119.00
9	Ir temperature sensor (MLX9061	₹ 910.00
10	Gps Module	₹ 439.00
11	Vibratioon motor	₹ 199.00
12	Sim Card	₹ 300.00
	total	₹ 15,433.00

3D Design



The image above shows the 3D model of the Smart Glove designed to assist visually impaired individuals by detecting environmental conditions.

- **Infrared Temperature Sensor:**
  Positioned at the fingertip, this sensor is responsible for detecting the temperature of objects the user interacts with. It helps differentiate between hot and cold surfaces, providing crucial safety feedback to the user.

- **On/Off Button:**
  Located on the side of the glove, this button allows users to power the entire glove system on or off. The placement ensures easy accessibility without interfering with natural hand movements.

Figure 1a, 1b – 3D Model of the Smart Glove showing sensor placement and controls.

This 3D model was created using Blender, and represents the structural design before hardware integration. The glove is ergonomically designed to house essential components while maintaining flexibility and user comfort.

Figure 1.2 – Top and side views showing camera and security system integration in the Smart Glove

The 3D render below illustrates two key components integrated into the smart glove to enhance functionality and user safety:

- **Negative Logic Mechanism (SOS & Anti-Theft):**
  This mechanism is embedded within the wrist area of the glove and works on a *fail-safe logic*. If the glove is forcefully removed or not worn properly, it triggers an automatic SOS alert and anti-theft warning. This ensures safety for the user in potentially dangerous situations.

- **Camera Integration:**
  A compact camera module is positioned on the top surface of the glove. It serves two main purposes:
  1. **Currency Recognition:** Assists visually impaired users in identifying currency denominations.
  2. **Pothole Detection:** Uses real-time video feed and image processing to detect potholes or obstacles on the walking path.

Figure 1c, 1d – Top and side views showing camera and security system integration in the Smart Glove.

These features make the glove a versatile and intelligent wearable aid, especially useful for blind or visually challenged individuals in urban environments.

Initial Design Sketches

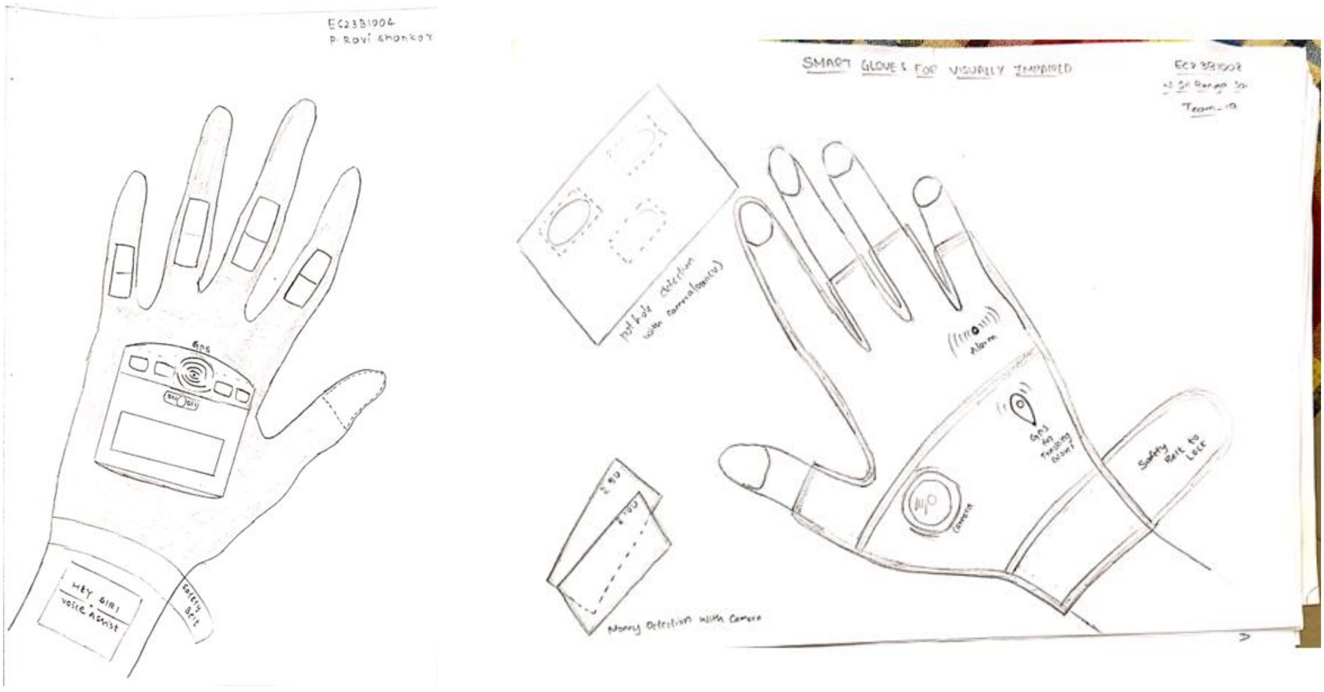


Fig. 2a 2b - Conceptual Sketches of Smart Glove Design

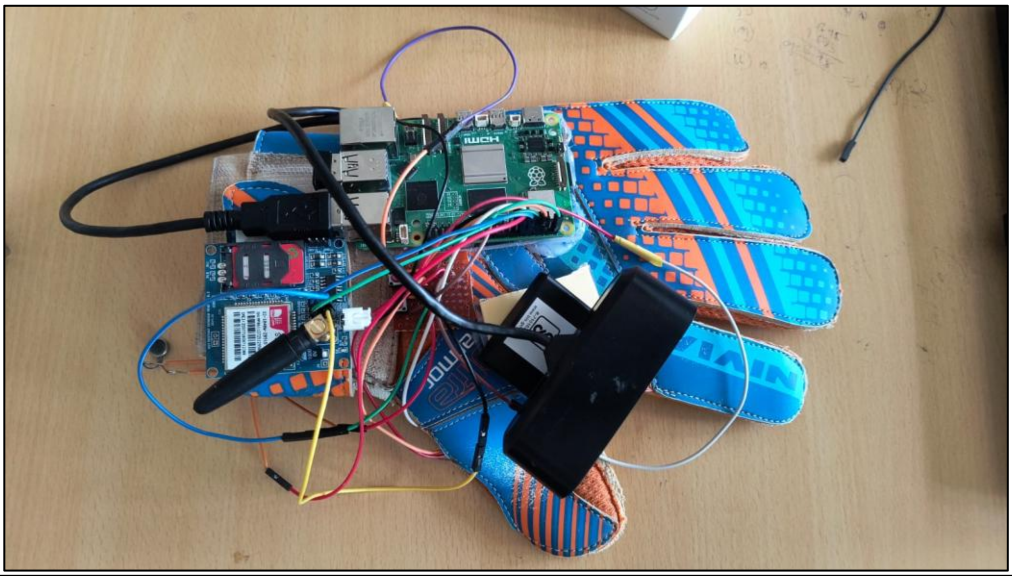
Before transitioning to the 3D modelling stage, we created a some rough conceptual sketches to ideate and refine the overall design of the smart glove. These sketches played a crucial role in shaping the final prototype by helping us:

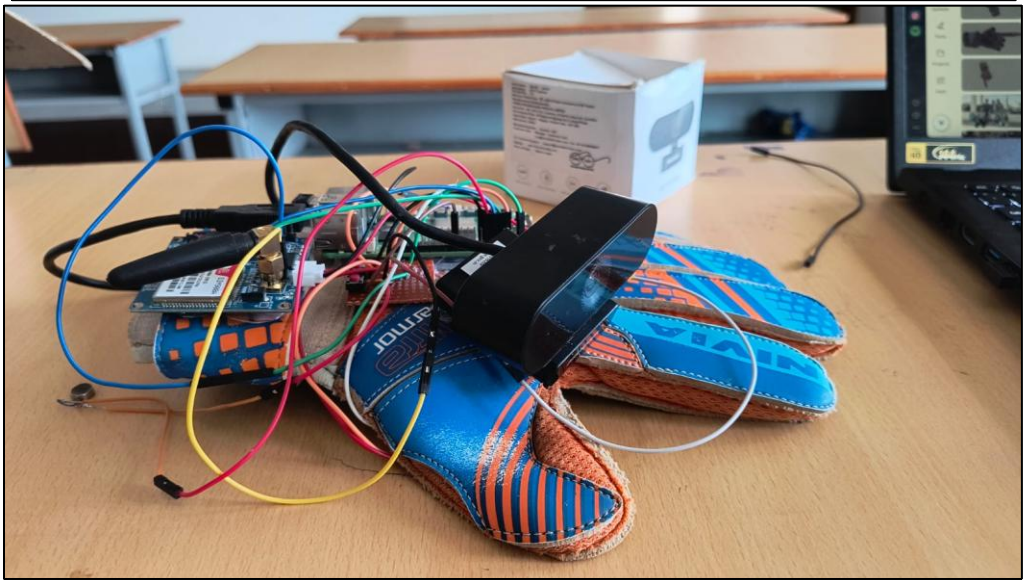
- Determine optimal placement of components such as the on/off switch, battery pack, and internal wiring.
- Evaluate ergonomics and user interaction, especially focusing on accessibility of controls and comfort during extended use.

- Experiment with various form factors and materials to ensure durability, flexibility, and functionality.
- Visualize the integration of electronics with the glove fabric while maintaining a clean and user-friendly exterior.

Each iteration allowed for progressive improvements, leading to a more robust, intuitive, and technically feasible design. These early sketches laid the groundwork for the 3D modelling and later, the physical prototype.

Prototype Images





Working Mechanism

The smart glove is designed to assist visually impaired users by integrating multiple technologies into a wearable form. The glove performs real-time environment sensing, object recognition, emergency communication, and security alerts using the following mechanisms:

1. Object and Pothole Detection with Voice Feedback

A compact camera module mounted on the glove continuously captures the surroundings. Using image processing algorithms, the system identifies road potholes or obstacles in the user's path. Upon detection, the glove sends a voice alert via Bluetooth to a connected earpiece informing the user of the nature and approximate distance of the hazard (e.g., *"Pothole detected at 3 meters ahead"*). This proactive notification enhances safety and navigation for the user in outdoor environments.

2. Currency Recognition System

When currency notes are placed near the glove's camera, the system uses optical character recognition (OCR) and image classification techniques to identify the denomination of the money. Once detected, the glove transmits the identified value via Bluetooth as an audio message (e.g., *"Fifty rupees detected"*), enabling the user to handle financial transactions independently.

3. Emergency Alert System with GPS Tracking

An emergency button is embedded on the glove. In case of distress, the user can press this button to trigger an automatic alert. The system retrieves the user's current location through a GPS module and sends it to a pre-registered caretaker via a call or message. This ensures quick assistance in case of emergencies.

4. Anti-Theft Mechanism

To ensure the safety of the glove and the user, an anti-theft feature is integrated using a grip or force sensor. If the glove is forcefully removed or grabbed by a stranger, the system detects this abnormal movement. An automatic alert is then sent to the caretaker, along with the user's location, to indicate a potential theft or security issue.

Each component of the glove is interconnected through a microcontroller that manages input from sensors, processes data, and facilitates communication. All audio alerts are conveyed using Bluetooth to maintain privacy and ensure real-time feedback.

Block Diagrams

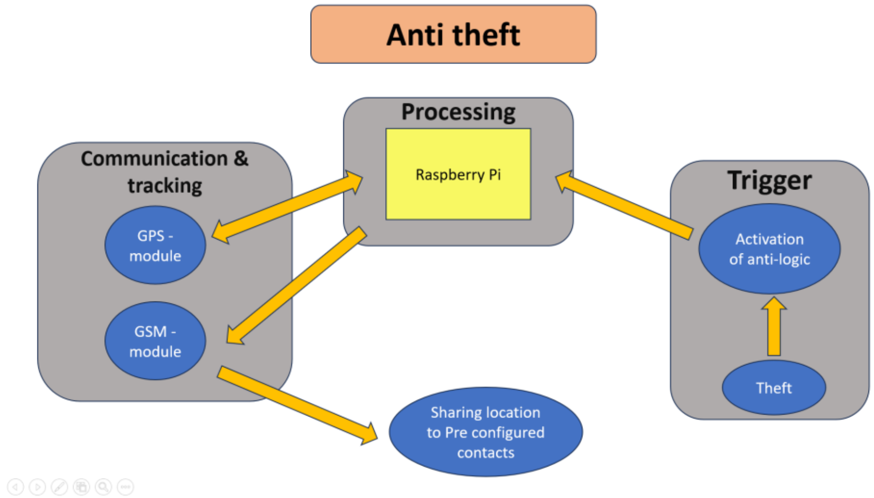


Fig. X: Anti-Theft System Architecture for Smart Glove

This block diagram illustrates the anti-theft mechanism integrated into the smart glove. The system is designed to detect unauthorized removal or tampering of the glove and immediately alert the user's caretaker.

Working Mechanism:

1. **Trigger Mechanism:**
   - The system monitors the glove for signs of theft using pre-defined **anti-logic triggers**.
   - When an unusual event (e.g., sudden removal or unauthorized access) is detected, it activates the theft detection logic.
2. **Processing Unit:**
   - The trigger signal is sent to the **Raspberry Pi**, which serves as the central processing unit.
   - The Raspberry Pi validates the event and initiates a security response.
3. **Communication and Tracking:**
   - Upon confirmation, the Raspberry Pi communicates with the **GPS module** to obtain the real-time location of the user.
   - Simultaneously, it utilizes the **GSM module** to send an alert message along with the current location to **pre-configured emergency contacts**.

4. **Emergency Response:**
    - The system ensures that the location data is accurately shared, allowing caretakers or authorities to respond immediately in case of a security breach.

This automated anti-theft mechanism adds an important safety layer, providing peace of mind and protection to visually impaired users against potential threats or loss of the device.

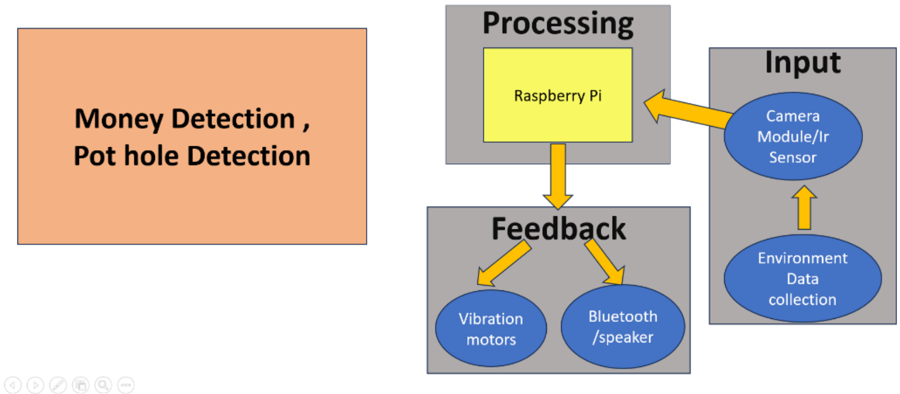


Fig. X - Functional Flow of Money and Pothole Detection System.

This block diagram represents the flow of operations for the money detection and pothole detection functionality in the smart glove system.

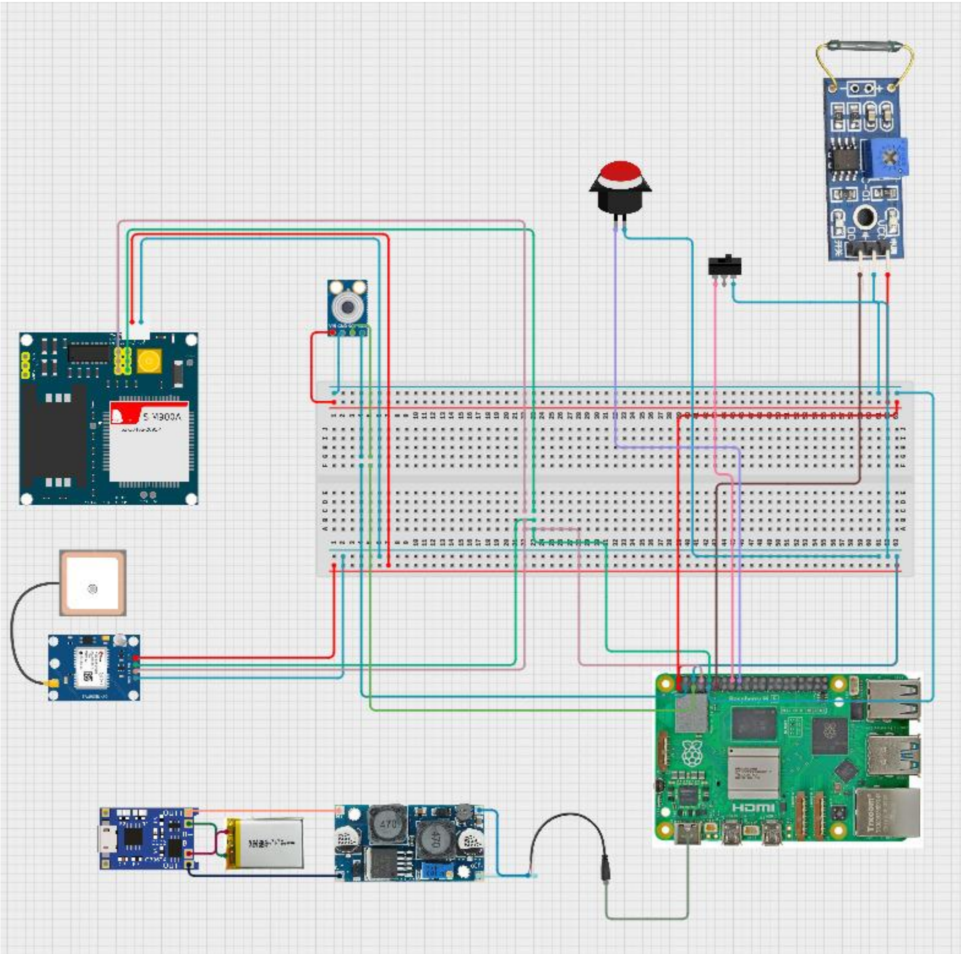
Working Mechanism:

1. **Input Layer:**
    - The system begins by collecting real-time environmental data using a **camera module and infrared (IR) sensor**.
    - These sensors detect road irregularities like potholes and recognize currency notes placed in front of the camera.
2. **Processing Unit:**
    - The collected data is sent to the **Raspberry Pi**, which processes the visual and sensor data using computer vision and machine learning algorithms.
    - Based on the processed information, the system identifies either a pothole ahead or the denomination of the currency note.
3. **Feedback Mechanism:**
    - Upon identification, appropriate feedback is provided to the user through:
        - **Vibration motors** for tactile alerts (e.g., intensity or pattern varies for pothole distance).

- **Bluetooth or speaker output** to deliver voice-based information, such as the currency value or the presence of a pothole at a specific distance.

This feedback mechanism ensures that visually impaired users receive timely and intuitive alerts, enabling safer mobility and reliable financial interactions.

CIRCUIT DIAGRAM



The circuit diagram presented above illustrates the complete hardware architecture of our IoT-based embedded system. The design integrates multiple sensors and modules with a Raspberry Pi acting as the central processing and control unit. The system is developed for real-time data acquisition, processing, monitoring, and communication.

Future Enhancements

1. Integration with AI for Advanced Object Recognition
   Future iterations can incorporate AI-based object detection to identify various obstacles such as steps, poles, vehicles, and moving objects in real time. This would significantly increase the safety and navigation accuracy for the user.

2. Voice Assistant Integration
   Integrating a voice assistant (offline or cloud-based) can help the user interact with the glove system through voice commands, enabling features like checking location, reading currency, or sending SOS messages with spoken prompts.

3. Vibration Pattern Feedback System
   To improve user experience, different vibration patterns can be used to convey specific alerts (e.g., pothole ahead, theft attempt, currency value, etc.), which would be more intuitive than generic buzzers.

4. Rechargeable Battery with Solar Charging Option
   Including a small solar charging panel embedded into the glove or on a wearable module can provide extended battery life and sustainability, especially for outdoor use.

5. Mobile App Integration
   Developing a companion mobile application for caretakers to monitor glove status, receive alerts, and track location in real-time would enhance caregiver support and allow for remote configuration of alerts and sensitivity levels.

6. Weather and Environment Detection
   Adding sensors for temperature, humidity, or rain detection can help blind users adapt to environmental conditions more safely, especially in extreme weather.

7. Gesture-Based Control
   Adding gesture recognition using IMU sensors could allow users to perform basic functions like activating pothole detection or emergency alerts through simple hand movements.

8. Compact & Flexible PCB Design
   The next version could focus on creating a compact, bendable PCB layout that seamlessly integrates with the glove fabric without compromising comfort or mobility.

9. Braille Output Surface
   As a long-term upgrade, integrating a small braille feedback area on the glove can provide text-based messages (like note values or directions) to users trained in braille.

10. Multilingual Audio Feedback
    Support for multiple languages in audio feedback would cater to users from diverse linguistic backgrounds, increasing the accessibility of the gloves globally.

Conclusion

The Smart Gloves for Blind People project aims to enhance the safety and independence of visually impaired individuals through a compact, wearable solution integrating pothole detection, currency recognition, Bluetooth-based feedback, GPS-enabled emergency and anti-theft alerts. By combining multiple assistive technologies into a single, user-friendly device and planning for PCB-based design to simplify connections, the project demonstrates a practical approach to real-world challenges. It lays the groundwork for future advancements in assistive wearables, promoting accessibility, security, and greater autonomy for blind users.

References

1)Patel, D., & Joshi, M. (2020).

"Smart Anti-Theft System for Wearables Using GPS and GSM."

2) Jocher, G. et al. (2023).

"YOLOv8: Real-Time Object Detection and Image Segmentation."