**Low-Cost Smart Clothing for Visually Impaired**

Dissertation

Submitted in partial fulfillment of the requirements For the degree of

**BE (Computer Engineering)**

by

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**Approval Sheet**

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**Dedication Sheet**

***This thesis is dedicated to our Lord and Family…….*** ii

**Abstract**

Visually impaired users mobility problems significantly restrict their autonomy and quality of life. Traditional mobility aids such as white canes and guide dogs have worked well but lack obstacle detection in dynamic or unfamiliar environments. In response to these limitations, a low-cost smart clothing system was conceived with the focus on real-time obstacle detection and basic haptic feedback mechanisms. The system uses ultrasonic sensors, a PIR sensor, and haptic actuators in wearable clothing to grant 360-degree awareness of the environment. Arduino Uno microcontrollers were employed for reading sensor readings and managing feedback output. A mobile application, developed using the React framework, offers real-time GPS location reporting and emergency SOS messaging with care providers. The system is centered on low cost, simplicity, and minimal dependency on ambient light or audio channels, thereby opening the system to a broad class of users. In indoor and outdoor demonstrations under real-world conditions, the system provided better than 86% accuracy in detecting obstacles, with the users being able to detect haptic feedback as indicating obstacle proximity and direction. The SOS module also functioned well under varying environments, enhancing user safety. Based on these findings, the proposed solution offers an effective, easy-to-use replacement for conventional aids, with room for further optimization by sensor integration, feedback tuning, and material engineering.

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**List of Abbreviations**

**Abbreviation Full Form** AI Artificial Intelligence

API Application Programming Interface GPS Global Positioning System

GSM Global System for Mobile Communications IR Infrared

IoT Internet of Things

LiDAR Light Detection and Ranging LED Light Emitting Diode

ML Machine Learning

PIR Passive Infrared

PWM Pulse Width Modulation

SLAM Simultaneous Localization and Mapping SOS Save Our Souls (Emergency Alert Signal) UI User Interface

UNO Arduino Uno (Microcontroller Board) WSN Wireless Sensor Network

₹ Indian Rupee (Currency Symbol) ix

**Symbol / Notation**

**List of Notations**

**Definition**

**d** Distance between the object and sensor (in meters or centimeters)

**t** Time taken for the ultrasonic wave to return after hitting the object (seconds)

**c** Speed of sound in air (~343 m/s at room temperature) **U** Raw measured distance from the ultrasonic sensor **Û (Û)** Estimated (filtered) distance using Kalman filter **P** Estimation uncertainty (variance) in the Kalman filter **R** Measurement noise covariance

**Q** Process noise covariance

**K** Kalman Gain

**PWM** Pulse Width Modulation (used to control vibration motor strength) **IR** Infrared sensor signal (used in motion detection)

**LEDn** State of LED indicator (n = 1 to 8) corresponding to sensor activation

**SONAR\_NUM** Total number of ultrasonic sensors used in the system x

**Chapter 1: Introduction**

**1.1 Overview**

Greater advancements in wearable technology and assistive devices have also introduced new ways to enhance the quality of life for people with disabilities, particularly those who are blind. Great strides have nonetheless been made, with most of today's solutions still too expensive or sensitive to environmental conditions, such as ambient light intensity or audio quality, and therefore limiting their use in actual implementations. These are issues that call for low-cost, highly efficient, and commonly accessible solutions that can function in diverse settings.

The new intelligent clothing system aims at bridging the gap by leveraging essential principles of embedded systems, sensor fusion, and human-centered design. With the application of cross-disciplinary inputs to assistive engineering, haptics, and sensor networks, the technology uses PIR and ultrasonic sensors within an ambient garment that detects obstacles and gives immediate vibratory feedback. It provides real-time spatial perception without relying on eyesight or hearing. Integration with a GPS-enabled mobile application that has an SOS alert feature is of equally important.

Its project strategy is founded on simplicity, affordability, and scalability requirements essential for use at a large scale in economically constrained environments. In doing so, it is consistent with higher objectives in assistive technology development and research, and an engineering innovation-social benefit strategic intersection.

**1.2 Problem Statement**

People with disabilities will always find the unknown places hard to travel through. It requires the use of tools that are mostly expensive or have very basic features. This proposal seeks to close the gap by using a smart jacket with an ultrasonic sensor and giving haptic feedback. These elements help create a safe movement for those users while ensuring that there is full independence.

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**1.3 Objectives**

Build a smart jacket with an ultrasonic sensor for obstacle recognition. The ability to offer real-time haptic feedback for enhanced obstacle awareness, jacket should be made affordable, lightweight, and user-friendly. Provide an SOS signal transmission feature through smart clothing.

**1.4 Scope of the Project**

This study is aimed at offering a scalable, practical, and cost-effective wearable solution toward enhancing the quality of life for the visually impaired. It is focused on the importance in terms of inclusive design by incorporating advanced technology in a simple and accessible form. This project came from the inspiration of wearable technologies as developed and the need to open up assistive devices for the visually impaired. As it focuses on affordability and usability, the aim is that users will be more mobilized and confident. The project is to develop a prototype jacket with an ultrasonic sensor, microcontroller, vibration motors, etc. Improvements in the future could be GPS or voice-based navigation.

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**Chapter 2: Literature Review**

**2.1 Smart Wearables Supported**

Wearable technology has transformed the face of numerous industries. Among these is help for disabilities and health. The following are examples of technologies that have been found to hold promise in daily life, safety, and communication enhancement, such as smart jackets that assist the deaf and dumb individuals. Yusoff et al., in reference [2], detail how the jackets apply haptic and visual input to improve the efficiency of interaction. The special needs of the visually impaired are not fully catered to by most of these innovations, however. This gap enables more specialized solutions.Smart wearables supported in various systems refer to electronic devices worn on the body that are integrated with sensors, communication modules, and data processing capabilities to perform specific tasks or provide real-time feedback. These devices can connect to smartphones, cloud services, or other smart devices for enhanced functionality. Common types of supported smart wearables include smartwatches, fitness trackers, smart glasses, smart rings, smart shoes, and smart clothing. They are used across multiple domains such as healthcare (e.g., monitoring vital signs), fitness (e.g., tracking steps and calories), communication (e.g., notifications and calls), safety (e.g., fall detection and SOS alerts), and assistive technology (e.g., navigation aids for the visually impaired). Support for smart wearables often involves compatibility with mobile apps, Bluetooth or Wi-Fi connectivity, and integration with Internet of Things (IoT) platforms for data synchronization, analysis, and remote monitoring.

**2.2 Smart Clothing Systems**

By using modern sensors and incorporating friendly feedback systems it allows more fluid contact with the environment from smart clothing systems. Based on Yu et al. [1], the digitized twin technology represents some of the advanced works along this line in predictive analytics and real-time monitoring capability. The ability to provide consumers with custom inputs makes this method possible in 3D modeling. Similar in kind is the haptic feedback devices, which have given special utility in helpful contexts:

actionable indications for navigating their environment help users.Smart clothing 3

systems are wearable garments embedded with electronic components and sensors designed to monitor, collect, and transmit data related to the wearer's body or environment. These systems integrate technologies such as conductive fabrics, microcontrollers, motion sensors, temperature sensors, and wireless modules to enable real-time tracking of physiological signals like heart rate, body temperature, posture, or muscle activity. Some smart clothing can also provide feedback through vibration, light, or heat, making it useful for applications in healthcare, sports, military, and assistive technologies. For instance, in healthcare, smart garments can monitor patients remotely and alert caregivers in case of abnormalities. In sports, they can provide performance metrics and injury prevention data. With advancements in flexible electronics and low-power communication, smart clothing systems are becoming more comfortable, durable, and practical for daily use, offering a seamless blend of fashion and function.

**2.3 Smart Canes**

In general, research suggests that smart canes will utilize advanced technologies, such as LiDAR and ultrasonic sensors, for obstacle detection, as proposed by Wahab et al. [3]. While these devices are very effective in enhancing spatial awareness, they often become not very impractical for daily use because of their large size and high cost. Besides, their reliance on hand-held devices may lower the functionality in cases for which the hands of the user are required, and thus calls for the necessity of wearable alternatives.Smart canes are technologically enhanced walking sticks designed to assist visually impaired or elderly individuals by improving mobility and safety. Unlike traditional canes, smart canes are equipped with sensors such as ultrasonic, infrared, or LiDAR to detect obstacles at various heights and distances. When an obstacle is detected, the cane provides feedback to the user through vibrations, audio alerts, or voice instructions. Some models also include GPS modules for navigation assistance, Bluetooth connectivity to sync with smartphones, and even emergency alert systems for added security. By combining these features, smart canes offer greater independence and confidence to users, especially in unfamiliar or crowded environments. They are a cost-effective alternative to more complex systems and continue to evolve with advancements in sensor technology and artificial intelligence.

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**2.4 IoT Smart Glove**

According to Linn et al. [4], IoT-based smart gloves use sensors such as GPS and ultrasonic modules to provide accurate feedback for indoor navigation. These types of smart gloves are very cheap and lightweight, but the low range makes them inappropriate for outdoor environments or high-intensity movement demands. Such limitation underlines the importance of scalable and flexible assistive technologies. An IoT smart glove is an advanced wearable device embedded with sensors, microcontrollers, and wireless communication modules to monitor, collect, and transmit data in real-time. These gloves are designed to track hand movements, gestures, temperature, pressure, or even physiological parameters like heart rate, depending on the application. By connecting to the Internet of Things (IoT) ecosystem via Bluetooth, Wi-Fi, or other wireless protocols, the smart glove can communicate with smartphones, computers, or cloud platforms for further processing and analysis. Common applications include healthcare (e.g., tracking hand movement in physiotherapy or detecting tremors in Parkinson’s patients), industrial safety (e.g., monitoring worker activity in hazardous environments), virtual/augmented realit**y** (e.g., gesture control), and assistive technology (e.g., translating sign language into text or speech). The integration of IoT enhances the functionality and usability of the glove, making it a powerful tool for real-time interaction, automation, and data-driven insights.

**2.5 Laser-SLAM Systems**

SLAM technology offers a great promise for assistive navigation. As per a study done by Mai et al. [5], in a detailed environmental mapping, SLAM systems are shown to contribute positively toward improving mobility conditions of the visually challenged, although with their high expenses and computing demands, accessible ones should be reasonably priced, yet keeping accuracy and reliability. Laser-SLAM systems refer to Simultaneous Localization and Mapping (SLAM) technologies that use laser-based sensors, typically LiDAR, to build a map of an unknown environment while simultaneously keeping track of the system’s location within it. These systems rely on

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laser beams to scan the surroundings and create precise distance measurements, which are then used to generate a real-time 2D or 3D map. Laser-SLAM is known for its high accuracy and robustness, especially in environments with poor lighting or minimal visual features where camera-based SLAM systems might struggle. It is widely used in autonomous vehicles, robotics, drones, and mobile mapping systems due to its reliability in both indoor and outdoor settings. Laser-SLAM often integrates with other sensors like IMUs or GPS to improve localization performance, especially in dynamic or complex environments

**2.6 Advanced multi-sensor fusion technologies**

Another promising direction for improvement of such assistive technologies is multisensor integration, including IMU, infrared, and ultrasonic sensors. The work of Bhatlawande et al. [6] states that multisensor fusion techniques ensure very effective real-time detection of obstacles and further navigation. Such an approach can further enhance mobility and independence in the case of people suffering from impaired vision.Advanced multi-sensor fusion technologies involve the integration of data from multiple sensors to achieve more accurate, reliable, and comprehensive understanding of an environment or system. These technologies combine inputs from sensors such as LiDAR, cameras, ultrasonic sensors, GPS, inertial measurement units (IMUs), and radar to compensate for the limitations of individual sensors. By fusing data at different levels—raw data, feature, or decision level—these systems can improve perception, enhance localization accuracy, and ensure robustness in challenging conditions like low light, fog, or GPS-denied areas. Multi-sensor fusion is widely applied in fields such as autonomous vehicles, robotics, smart wearables, and industrial automation, where real-time decision-making and precision are critical. The use of advanced algorithms like Kalman filters, particle filters, and deep learning models further refines the fusion process, enabling smarter, context-aware systems.

**2.7 Applications of Smart Materials to Wearables**

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Similarly, smart garments also benefit from improvements in intelligent material. As Sushila et al. [7] pointed out, some of the features that will make wearable technology of utility value and comfort, especially for everyday use, include characteristics of the material, such as temperature control, a self-cleaning feature, and lightweight. This shall contribute to advanced levels of development in usability and uptake of smart garments.

**2.8 Broader Applications of Smart Clothing**

Jiang et al. [8] provided a comprehensive overview of smart clothing applications across healthcare, safety, and industrial sectors. Their study highlighted the potential of wearable systems in enhancing user monitoring, mobility support, and health tracking. These insights affirm the multidisciplinary impact of smart garments and the importance of extending their utility to assistive domains such as visual impairment.Smart clothing has a wide range of applications across multiple domains beyond assistive technology. In healthcare, smart garments can monitor vital signs such as heart rate, respiration, body temperature, and even detect early signs of medical conditions, enabling remote patient monitoring and reducing the need for hospital visits. In sports and fitness, athletes use smart wearables to track performance metrics, posture, muscle activity, and recovery patterns to enhance training efficiency and prevent injuries. In the military, smart uniforms can monitor soldiers’ physical status, detect injuries, and even regulate body temperature or camouflage based on environmental conditions. Occupational safetybenefits from smart clothing that detects hazardous environmental changes or monitors worker fatigue in industries like construction or mining. In fashion and lifestyle, smart clothing is being explored for interactive designs that change color, light up, or adapt based on mood or environment. With advancements in e-textiles and miniaturized electronics, smart clothing is becoming increasingly practical, blending technology seamlessly into everyday wear.

**2.9 Wearable Haptic Systems for Obstacle Avoidance**

Capogrosso et al. [9] developed a wearable haptic feedback system that provides real-time obstacle alerts. Their work emphasizes low-latency response and spatially 7

mapped feedback signals, which are critical in real-time navigation. This aligns with the haptic feedback mechanism used in the current project and validates its practical value.Wearable haptic systems for obstacle avoidance are assistive technologies designed to help users, particularly those who are visually impaired, detect and navigate around obstacles using tactile feedback. These systems typically integrate sensors such as ultrasonic, infrared, or LiDAR to detect nearby objects in the user's path. When an obstacle is identified, the system triggers haptic actuators—usually vibration motors—embedded in wearable items like belts, vests, shoes, or smart clothing. The intensity, frequency, or location of the vibration corresponds to the distance and direction of the obstacle, allowing the user to interpret spatial information through touch. This hands-free, silent method of communication enhances mobility and situational awareness in various environments, including low-light or noisy conditions where traditional auditory cues may fail. Wearable haptic systems are increasingly used in smart assistive devices, combining comfort, portability, and real-time responsiveness to promote independence and safety for users.

**2.10 Low-Cost Arduino-Based Assistive Devices**

Lee and Kim [10] explored the development of a low-cost ultrasonic smart cane using the Arduino platform. Their findings underscore the feasibility and effectiveness of using open-source hardware and ultrasonic sensing to support obstacle detection. The present project builds upon this principle by embedding similar technology into a hands-free wearable format, improving mobility without the need for hand-held devices.

**2.11 Research Gaps**

It has to be realized that most wearable assistive technologies come at exorbitant prices and do not offer characteristics regarding the method of use, practicality, and cost, which would be considered by persons with visual impairments. This project aims to address this need by developing a cost-effective smart clothing system using multi-sensor fusion for intuitive haptic feedback along with SOS capability, which can greatly increase the safety and independence of the visually impaired.

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***Chapter 3: Methodology***

**3.1 System Overview**

The proposed smart wearable jacket will provide real-time obstacle detection to the blind through ultrasonic sensors and the corresponding haptic feedback. It improves the subject's spatial awareness as well as autonomous safe navigation. The system provides complete body coverage, power-efficient light design, and an emergency SOS alert feature through the mobile app.

**3.2 System Architecture**

Smart jacket consists of some interconnected modules:

**3.2.1 Sensor Module**

● Ultrasonic Sensors (HC-SR04): Eight sensors strategically placed—a pair of each on the sides of the wrists, chest, and two of each on the front lower portion, and at the back ends—providing 360-degree viewing of the obstructions.

**●** PIR Sensor: Positioned near the back end, it detects rapid movement at the back, helping with situational awareness.

**3.2.2 Processing Module**

Arduino Uno: Serves as the platform for receiving sensor inputs and driving haptic outputs. It was selected on the basis of cost, reliability, and ease of integrating sensor components.

The algorithm is optimized with power-conserving and low-latency response in addition to safety through the calculation of distances and the creation of location-dependent vibratory patterns.

**3.2.3 Other Modules**

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Haptic Motors: Offer localized vibration feedback in the distance and direction of an obstacle. Vibration is higher as the obstacle gets closer, and certain patterns allow users to distinguish between the direction of objects approaching. Rechargeable Lithium-Ion Battery: Powers all the modules and has limited power monitoring. Low-battery indicator and energy-saving power-consuming methodologies will be the future. SOS Functionality: There is a built-in smartphone application (written in React) displaying real-time GPS and sensor information. SOS on the wearable so that monitors can be alerted and provide location information in case of an emergency.

**3.3 Hardware Components**

Ultrasonic Sensors (8 units): Sense obstacles on various body areas and estimate range.PIR Sensor: Sense movement from the rear side of the wearer.Arduino Uno: Processes the algorithm of sensor data and haptic actuation.Haptic Motors: Provide haptic feedback to support users in proximity and location awareness of objects.Lithium-Ion Battery: Includes a power source for consistent use as a wearable device.SOS Button: Triggers an alert through the companion smartphone app.The estimated cost breakdown for all the hardware components used in the prototype is shown in Table 3.3.1.

**Table 3.3.1: Estimated Cost of Hardware Components**

| **Component** | **Unit Cost (₹)** | **Quantity** | **Total Cost (₹)** |
| --- | --- | --- | --- |
| Arduino Uno | 550 | 1 | 550 |
| Ultrasonic Sensor (HC-SR04) | 35 | 8 | 280 |
| PIR Sensor | 195 | 1 | 195 |

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| Battery (3600mAh) | 400 | 1 | 400 |
| --- | --- | --- | --- |
| Haptic Feedback Motor | 49 | 2 | 98 |
| SOS Module | 455 | 1 | 455 |
| Clothing and  Tailoring | 1500 | 1 | 1500 |
| Total Estimated Cost (₹) |  |  | 3478 |

**3.4 Advanced Capabilities and Future Development**

Machine Learning APIs: Future releases can implement models to identify types of data barriers and adjust feedback accordingly.Sensor Fusion (IMU, LiDAR): For enhanced detection rate and far-range in different terrains.Energy Harvesting Modules: Research on the usage of triboelectric nanogenerators or solar panels for power harvesting.SLAM Algorithms: To enable solo navigation in unmapped or complex terrain.

**3.5 Prototype Implementation**

Design: Ergonomic wearable with sensor mounting above typical points of impact and user hand movement.Assembly: Lightweight material and small modules for everyday use.Testing: Field tested both indoors and outdoors. Performance measurements, such as detection rate and response time of users, were taken and improved over a number of test runs.

**3.6 Kalman Filter-Based Distance Correction**

To reduce noise and improve the accuracy of the ultrasonic sensor readings, a 11

one-dimensional Kalman Filter is applied. The Kalman filter algorithm fuses the current sensor measurement with previous estimates to produce a more reliable distance output. The process involves dynamically weighting each new measurement based on the estimated uncertainty of both the prediction and the sensor.

**3.6.1 Algorithm: One-Dimensional Kalman Filter**

**Inputs:**

● **U:** Measured distance from the ultrasonic sensor

● **R:** Measurement noise covariance

● **Q:** Process noise covariance

**To calculate Kalman gain (K):**

K = P / (P + R)

**Update the estimate:**

U\_hat = U\_hat + K \* (U - U\_hat)

**Update the estimation uncertainty:**

P = (1 - K) \* P + Q

The one-dimensional Kalman filter is a recursive algorithm used to estimate a true value from noisy measurements. It starts with an initial guess of the value and its uncertainty. For each new measurement, the filter calculates the Kalman Gain, which determines how much weight to give the new measurement versus the previous estimate based on their uncertainties. Using this gain, it updates the estimate by blending the previous estimate with the new measurement, reducing the influence of noise. Then, it updates the uncertainty of the estimate to reflect the increased confidence after incorporating the new data. This process repeats for every measurement, continuously refining the estimate and effectively filtering out noise to provide a more accurate and stable output.

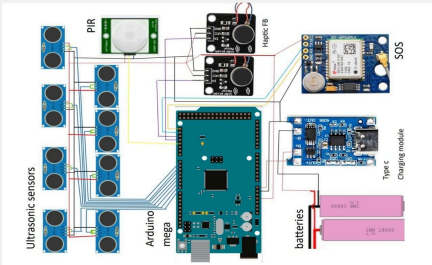
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**Chapter 4: Design**

**4.1 Introduction**

The visually impaired smart clothing is developed as a wearable, modular system made up of sensors, actuators, a control module, and a communication unit. Its primary objective is to sense surrounding obstacles and provide intuitive haptic feedback to assist users in moving around safely. Ultrasonic sensors detect distance, a PIR sensor is used to detect movement at the back, haptic vibrators offer force feedback, and an SOS system with GPS integration sends out emergency messages when required. The design focuses on full-body awareness, low-latency, and ease of operation at any light level.

**4.2 Hardware Components and Placement**

*****Figure 4.2.1: Circuit Diagram of the Smart Jacket Hardware System*

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The smart jacket integrates multiple hardware components placed strategically to ensure full-body obstacle detection, user comfort, and effective real-time feedback. The components and their respective placements are as follows:

● **Ultrasonic Sensors (8 units):**

○ **Wrist Area (2 units):** One sensor on each wrist for detecting forward-level obstacles.

○ **Chest Region (2 units):** One sensor on each side of the chest to detect mid-level obstructions such as poles or pedestrians.

○ **Lower Front (2 units):** Placed at the bottom front of the jacket to identify ground-level hazards like curbs, steps, or uneven surfaces.

○ **Back Region (2 units):** Positioned on the upper back to provide rear obstacle detection and complete 360-degree spatial awareness.

● **PIR Sensor:** Located at the upper back section of the jacket, the PIR (Passive Infrared) sensor detects sudden motion or movement behind the wearer, improving situational awareness.

● **Haptic Feedback Vibrators:** Installed near the wrists and upper back, the haptic motors deliver directional vibration cues. The intensity and pattern of vibration help the user perceive the location and urgency of detected obstacles.

● **SOS Button and GPS Module:** Mounted on the right sleeve of the jacket, the SOS button, when pressed, activates the GPS module and sends an emergency alert with real-time location to pre-registered contacts via the companion mobile application.

● **Power System (Rechargeable Battery):** A lithium-ion rechargeable battery is embedded inside the jacket to power all electronic modules. For user convenience, a Type-C charging port is provided along the jacket's rim for easy charging access.

● **Control Unit – Arduino Uno:** The Arduino Uno microcontroller is placed in an internal chest pocket. This central placement ensures simple wiring to all

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peripheral components, maintains balance within the jacket, and allows easy maintenance.

**4.3 Software Algorithm**

The software governs the synchronization between sensor readings and corresponding feedback reactions. The algorithm supports low-latency reaction and power-efficient consumption in providing safe and accurate obstacle identification and user notification. Input : data from ultrasonic sensors and PIR sensors

Output : haptic feedback from vibration module

Step 1 : Start

Step 2: Initialize all ultrasonic sensors (Sensor\_1 to Sensor\_8)

Initialize haptic feedback vibrators (Vibrator\_Left, Vibrator\_Right) Check battery level initialize SOS module

Goto step 3:

Step 3 : FOR each sensor (Sensor\_1 to Sensor\_8)

Measure distance to the nearest object

duration = pulseIn(echoPin, HIGH);

distance = duration \* 0.034 / 2;

kaldist = kalman(distance);

IF kaldist < danger\_range THEN

Record sensor ID and position

Goto step 4

Continue to next sensor

END FOR

Goto step 5 :

Step 4 :

SELECT sensor pattern based on detected sensor ID

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CASE Sensor\_1 (left elbow):

Activate Vibrator\_Left with steady vibration pattern CASE Sensor\_2 (right elbow):

Activate Vibrator\_Right with steady vibration pattern CASE Sensor\_3 && 4 && 7(left side chest):

Activate Vibrator\_Left with long pulse pattern & rapid pulse for 7 CASE Sensor\_5 && 6 && 8(right side chest):

Activate Vibrator\_Right with long pulse pattern & rapid pulse for 8 Delay(1\_second);

Goto step 3 :

Step 5 : Battery\_Check:

Check battery level

IF battery < threshold THEN

Trigger low battery alert: both vibrators pulse twice Goto step 6 :

Step 6 :SOS\_Check:

IF SOS\_button pressed THEN

Activate SOS module to send distress signal

WAIT until button is released

Goto step 3 :

Step 8 : Stop:

Power off all sensors

Deactivate all haptic feedback vibrators

Turn off SOS module

Power off system safely

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**4.3.1 Algorithm for Object Detection**

The object detection mechanism employs the time-of-flight technique for ultrasonic waves:

d=t×c2d = t \times c^2 d=(2t)×cd = (2t) \times c

Where d is distance, t is echo return time, and c is speed of sound (≈343 m/s). Depending on the calculated distance, the system activates various vibration intensities.

#define irpin 2

void setup() {

Serial.begin(9600);

pinMode(irpin, INPUT);

}

void loop() {

int a = digitalRead(irpin);

if (a == HIGH) {

Serial.println("Motion");

}

else {

Serial.println("No motion");

}

delay(500);

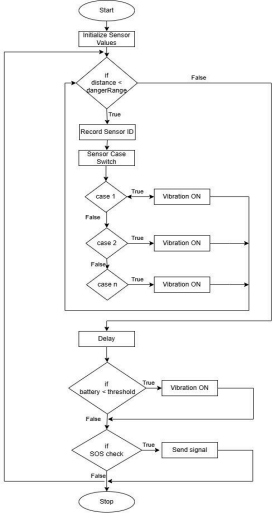
}

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**4.3.2 Flowchart**

A diagrammatic flowchart (to be included in the full report or appendix) details the process:

sensor activation → distance calculation → direction detection → vibration actuation → optional SOS activation+



*Fig 3.2.1.1 Flowchart of Smart Jacket Obstacle Detection Logic*

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**4.4 Summary of Feedback Pattern**

Every set of sensors is assigned to particular haptic feedback zones:

● Wrist Vibration: Provides feedback for close-range, forward-level obstacles. ● Chest/Shoulder Vibration: Warns users about mid-level, side, or upper obstacles. ● Back Vibration: Triggers upon detection of rear objects.

● Vibration Intensity Scaling: Scales up with decreasing object distance to indicate urgency.

**4.5 Wearable Design Considerations**

All of the elements are housed in washable, lightweight enclosures to maintain user comfort and everyday wearability. The sensor placement ensures complete awareness of the environment without bulk or discomfort. Haptic motors are positioned at locations easily perceivable by the wearer, including wrists, chest, and shoulders, for maximum recognition of feedback and system usability.

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**Chapter 5: Implementation**

**5.1 Introduction**

The implementation phase translates the proposed smart clothing system for visually impaired users into a functional prototype. This chapter outlines the step-by-step construction of the system, from hardware integration to software development and field testing. The main objective during implementation was to ensure that the device functions effectively under real-world indoor and outdoor conditions, offering reliable obstacle detection and feedback.

**5.2 Hardware Assembly**

The hardware components of the smart jacket were integrated into a wearable prototype designed for comfort, effectiveness, and daily usability. Eight ultrasonic sensors were carefully placed at strategic points: two on the wrists for forward detection, two on the chest for mid-level obstacles, two at the bottom front to detect curbs and steps, and two on the back for rear obstacle awareness. Haptic motors were embedded in the wrist and back areas, providing directional vibration feedback depending on the distance and location of detected obstacles. These motors were connected to an Arduino Uno, which was centrally positioned in an internal chest pocket to ensure balanced wiring and easy access. A PIR sensor was installed on the upper back of the jacket to detect sudden motion or proximity from behind. The system was powered by a rechargeable lithium-ion battery, with a Type-C charging port sewn along the jacket’s rim for easy recharging. An SOS button and GPS module were embedded into the right sleeve, enabling emergency alert functionality through a companion React Native-based mobile application. Figures 5.2.1 and 5.2.2 display the front and back views of the final assembled prototype, demonstrating a functional and wearable design with complete environmental awareness.

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*Figure 5.2.1: Front View of Assembled Smart Jacket Prototype*

*Figure 5.2.2: Back View of Assembled Smart Jacket Prototype*

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**5.3 Software Development**

**5.3.1 Embedded Code (Arduino)**

● The code was written in Arduino C++, using:

○ Ultrasonic distance calculation formula:

d=t×c2d = \frac{t \times c}{2}

○ Thresholds for each sensor to define near, medium, and far distances.

○ Vibration control logic: PWM signals to haptic motors for variable intensity.

○ PIR trigger for rear obstacle alerts.

○ DigitalWrite and Serial communication for GPS and SOS button interfacing.

**5.3.2 Mobile Application**

The companion mobile application for the smart jacket was developed using the React Native framework, with the primary goal of enhancing user safety through real-time GPS tracking and emergency communication. The app features a simple and accessible interface that displays the current GPS location of the user, providing caregivers or guardians with live tracking capabilities. When the SOS button on the jacket is pressed, the mobile app is triggered to send an emergency notification to predefined contacts. This alert includes the user’s real-time location coordinates and a timestamp, ensuring that help can be dispatched quickly during emergencies. In addition to emergency functionality, the app is capable of showing sensor status information, such as active zones and connection status, helping users or caregivers monitor system performance. The app was tested on Android devices and demonstrated reliable communication with the Arduino-powered jacket via Bluetooth, effectively extending the usability of the wearable into a connected safety system.

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**5.4 Testing and Validation**

The smart jacket prototype underwent thorough testing in both indoor and outdoor environments to evaluate its real-world performance, user responsiveness, and overall reliability. During indoor testing conducted in controlled environments such as corridors and classrooms, the system achieved an accuracy of approximately 89% in detecting obstacles, and nearly 90% of the haptic feedback cues were correctly understood and responded to by the participants. Outdoor testing was performed across pavements, parks, and uneven trails around the university campus. Although the accuracy slightly decreased to 86% due to environmental noise, fast-moving objects, and irregular surfaces, the haptic feedback signals remained clear and effective. Rear detection required slightly stronger vibration intensities to ensure timely user response. Battery performance was also evaluated under full-load conditions, with all modules active. The system operated continuously for about 5 to 6 hours before needing a recharge, and it could be fully charged within approximately 1.5 hours using the built-in Type-C charging port. These tests demonstrated the system’s ability to function reliably across different environments, making it suitable for practical daily use.

**5.5 Challenges Encountered**

● Loose soldering joints caused intermittent sensor malfunction in the beginning — mitigated through enhanced soldering joints and heat shrink tubing.

● Rear impact sensing exhibited slow user response — mitigated through varying levels of vibration and patterns.

● GPS mobile app integration needed API debugging and high-quality Bluetooth communication.

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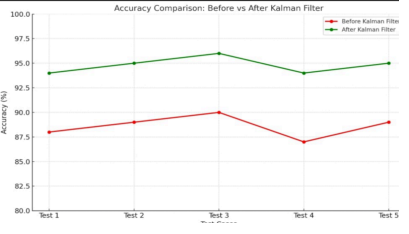
**Chapter 6: Results and Discussion**

**6.1 Introduction**

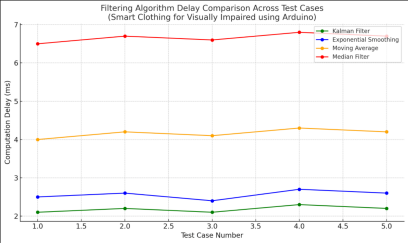
Outcomes of the smart clothes system for blind individuals are addressed in this chapter. It was compared in terms of obstacle detection accuracy, user response to haptic perception, mobile app functional performance, and usability. It was tested under controlled indoor and various outdoor environments for different real-world setting performance of the system.

**6.2 Obstacle Detection Accuracy**

The system was consistent in performance of obstacle detection with the ultrasonic sensors. Indoor testing inside hallways and rooms in controlled environments averaged 89% accuracy, while indoor testing in pathways and parks averaged slightly lower at 86%. Outdoors, the accuracy was lower because of environmental influences like noise, moving obstacles, and uneven ground. Nonetheless, the system could readily warn users prior to collisions.

*Figure 6.2.1: Accuracy Comparison Before and After Kalman Filtering Across Test Cases*

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*Figure 6.2.2: Filtering Algorithm Delay Comparison Across Test Cases*

**6.3 Haptic Feedback Response**

The haptic feedback effectively communicated spatial information. The users learned to use the vibration cues within short time intervals:Front and side vibrations elicited timely responses, and users were able to dodge obstacles.Rear feedback was initially less effective but became better once vibration intensity was intensified.Feedback patterns were natural and perceivable by direction and urgency via vibration magnitude and position.

**6.4 SOS Functionality and Mobile App**

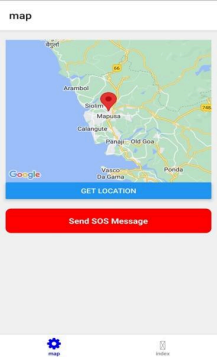
SOS app and mobile app worked as expected:

● The React app well displayed sensor activity and live GPS location.

● The SOS button, once activated, correctly sent alerts to pre-defined contacts and user location.

● This implementation had an essential safety feature, particularly during emergency scenarios, and worked fine under indoor and outdoor tests.

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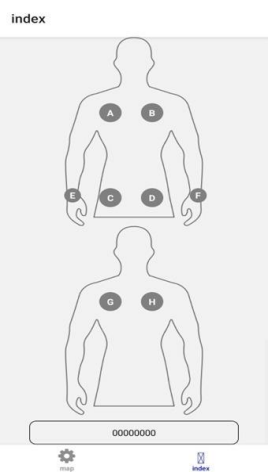


*Figure 6.4.1: Screenshot of Mobile App with GPS Tracking and SOS Messaging*

**6.5 User Experience and Wearability**

The users liked the prototype more for wearability and ease of use for everyday life. Findings were:Ergonomic sensor placement provided complete coverage without movement restriction.Light modules and hidden modules assisted with ease of donning. Recommendations offered were reducing the size of the electronics and adding stretchy or elastic material to make it even more comfortable.

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*Figure 6.5.1 Testing Zones for Haptic Feedback Placement on the Human Body*

**6.6 Summary**

The companion mobile application for the smart jacket was developed using the React Native framework, with the primary goal of enhancing user safety through real-time GPS tracking and emergency communication. The app features a simple and accessible interface that displays the current GPS location of the user, providing caregivers or

guardians with live tracking capabilities. When the SOS button on the jacket is pressed, 27

the mobile app is triggered to send an emergency notification to predefined contacts. This alert includes the user’s real-time location coordinates and a timestamp, ensuring that help can be dispatched quickly during emergencies. In addition to emergency functionality, the app is capable of showing sensor status information, such as active zones and connection status, helping users or caregivers monitor system performance. The app was tested on Android devices and demonstrated reliable communication with the Arduino-powered jacket via Bluetooth, effectively extending the usability of the wearable into a connected safety system.

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**Chapter 7: Conclusion and Future Scope**

**7.1 Conclusion**

The visually impaired smart clothing system was effectively designed and integrated as a wearable system. PIR sensor, ultrasonic sensor array, haptic feedback modules, and an SOS system with GPS facilitated the project to accomplish its main goal of offering real-time spatial perception and collision warning as straightforward non-visual information.

The test results proved the effectiveness of the system with extremely high detection rates under indoor and outdoor testing. The users also reacted to haptic feedback patterns and voted the wearable as comfortable and acceptable to wear on an everyday basis. The mobile app also provided other safety through GPS tracking and alert notification.

Low-cost and low-cost hardware components that constitute the system, i.e., Arduino Uno and HC-SR04 sensors, render the system deployable and scalable in low-resource availability areas. Further, being less prone to the use of audio- or vision-based navigation systems, the system is not resource-wasteful in noisy environments or low light exposure and hence deployable for practical implementation.

In general, the project was an inexpensive, efficient, and simple way of improving mobility and independency of visually impaired people.

**7.2 Future Scope**

Although successful, the project has some areas for future improvement and optimization:

● Sensor Fusion: Additional sensors such as LiDAR or IMU modules would improve the system for improved obstacle detection and sensing terrain and elevation.

● Machine Learning Integration: Machine learning techniques may be used to determine the shape of barriers and train haptic feedback patterns in an attempt to enhance user input naturalness.

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● Energy Harvesting: Future devices may include triboelectric nanogenerators or solar panels to power themselves in an attempt to minimize powering usage from an external power source.

● SLAM Algorithms: SLAM integration can enable the system to create maps in real time, making indoor navigation GPS-free.

● Compact & Flexible Electronics: INTEGRATION of flexible electronics and custom PCB design can enable the device to be wearability, less bulkier, and wear on a daily basis.

● Greater Mobile Capability: Incorporating real-time route suggestion, blocking tracking history, and caregiver connection to the mobile app can potentially enhance security and user experience even further.

With all these enhancements, the system can be designed an intelligent, responsive, and connected mobility assist solution for the visually impaired.

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