CSE 564 Project Report Number 3

Team 21

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# Received Requirements

# 1.1. Sensor Data Acquisition and Preprocessing (Received Function Requirement 1) [(By Sebastian Bersch)](https://www.mdpi.com/1424-8220/14/3/4239)

# 1.1.1. Feature: Data Collection from Multiple Sensors

# 1.1.2. Requirement Source: Stakeholder.

# 1.1.3. Inputs and Stimulus:

# Inputs: Continuous data streams from LiDAR sensor, cameras, radar sensors.

# Stimulus: Ongoing sensor data flow.

# 1.1.4. Sequence of Operations and Responses:

# Operation 1: The system establishes communication channels with multiple sensors, including LiDAR, cameras, and radar.

# Response 1: The system verifies data synchronization and connection stability with each sensor to ensure uninterrupted data acquisition.

# Operation 2: The system continuously collects data from each sensor, receiving raw sensor data frames at a specified frequency.

# Response 2: The system buffers incoming data frames, ready for subsequent processing.

# Operation 3: The software monitors sensor health and connectivity.

# Response 3: If a sensor becomes unresponsive or encounters errors, the system generates an alert and takes appropriate action, ensuring data integrity.

# 1.2. Voice Assistant Integration (Received Function Requirement 2)[(By S. Kalpna)](https://www.researchgate.net/publication/347553984_Voice_Recognition_Based_Multi_Robot_for_Blind_People_Using_Lidar_Sensor)

# 1.2.1. Feature: Integration with common voice assistants (e.g., Siri, Google Assistant).

# 1.2.2. Requirement Source: Stakeholder.

# 1.2.3. Inputs and Stimulus:

* Inputs: Microphone input from the user.
* Stimulus: User-initiated voice commands.

1.2.4. Sequence of Operations and Responses:

* Operation 1: The system integrates with common voice assistants, such as Siri and Google Assistant.
* Response 1: The system establishes a seamless connection to the selected voice assistant, enabling users to interact with the LiDAR guidance system using voice commands.
* Operation 2: When a user issues a voice command, the system captures the audio input through the microphone.
* Response 2: The system processes the voice command using a speech recognition algorithm to interpret the user's intent.
* Operation 3: The system executes the appropriate action based on the recognized voice command, enhancing user interaction and control of the LiDAR guidance system.

# 1.3. Optimized Battery Life (Received Performance Requirement 1) [(Carlo Canziani )](https://www.eenewseurope.com/en/iot-wireless-sensors-and-the-problem-of-short-battery-life/)

# 1.3.1. Feature: The system should operate in a way that the power consumption is minimal as much as possible.

# 1.3.2. Requirement Source: Stakeholder.

# 1.3.3. Static Numerical Requirement: The system should consume no more than 10% of the smartphone battery per hour during active usage.

# 1.3.4. Dynamic Numerical Requirement: The system should automatically reduce power consumption during periods of inactivity and provide a low-battery warning to the user, activating when the battery falls below 20%.

# 1.4. Obstacle Alert Threshold (Received Performance Requirement 2) [(Subramaniam)](https://www.sciencedirect.com/science/article/pii/S1270963816301900)

# 1.4.1. Feature: User will get control of adjusting obstacle alert threshold.

# 1.4.2. Requirement Source: User Feedback.

# 1.4.3. Static Numerical Requirement: Users should be able to customize the obstacle alert threshold within a range of 1 to 5 meters.

# 1.4.4. Dynamic Numerical Requirement: The system must adjust the alert sensitivity in real-time based on the user's selected threshold within a maximum response time of 0.5 seconds.

# 1.5. Audio Feedback Customization (Received Interface Requirement 1) [(Apple)](https://developer.apple.com/documentation/avfoundation/additional_data_capture/capturing_depth_using_the_lidar_camera)

# 1.5.1. Feature: Users should be able to specify their preferences for audio feedback volume, pitch, and voice type.

# 1.5.2. Requirement Source: User Feedback.

# 1.5.3. Source of Input or Destination of Output:

# Source of input: Buttons.

# Source of output: Speakers/headphones.

# 1.6. Gesture Control (Received Interface Requirement 2) [(Ryan Kealey)](https://cradpdf.drdc-rddc.gc.ca/PDFS/unc350/p812545_A1b.pdf)

# 1.6.1. Feature: The system should recognize user-defined gestures for controlling specific functions of the LiDAR guidance system.

# 1.6.2. Requirement Source: Stakeholder.

# 1.6.3. Source of Input or Destination of Output:

# Source of input: IR sensor data.

* Source of output: System response to recognized gestures.

# 1.7. Localization and Multilingual Support (Received Logical, Database, and/or Reuse Requirement 1) [(Multilingual)](https://rubric.com/en-us/multilingual-software-development/)

# 1.7.1. Feature: The system should support multiple languages and provide navigation and obstacle alerts in the user's preferred language.

# 1.7.2. Requirement Source: Stakeholder.

# 1.7.3. Types of data and/or operations performed:

# Types of data: Language preferences, multilingual audio prompts.

* Operations performed:
  + The system allows users to select their preferred language for audio feedback and alerts.
  + It supports multiple languages for providing navigation directions.
  + The system retrieves the chosen language data from the database, ensuring accurate language-specific guidance.

# 1.8. Data Privacy and Security (Received Logical, Database, and/or Reuse Requirement 2) ([Mahamodou Kante)](https://www.researchgate.net/publication/320409081_A_Review_of_Big_Data_Security_and_Privacy_Issues)

# 1.8.1. Feature: The system must adhere to data privacy and security regulations and protect user data, including location and personal information.

# 1.8.2. Requirement Source: Regulatory Guidelines.

# 1.8.3. Types of data and/or operations performed:

* Types of data: User location, voice commands, and preferences.
* Operations performed:
  + The system securely stores user data, ensuring encryption and access controls.
  + It anonymizes and protects location data.
  + Complies with relevant privacy laws and regulations, ensuring user consent for data collection and usage.
  + Conducts periodic security audits and updates to address vulnerabilities and emerging threats.

# 

# Derived Requirements

# Derived Function Requirement 1: Real-time Obstacle Detection

# Feature: Real-time Obstacle Detection

# Requirement Source: Stakeholder

# Inputs and Stimulus:

# Inputs: Raw LiDAR sensor data, precise GPS coordinates of the user's location

# Stimulus: Continuous and high-frequency sensor data streams

# Sequence of Operations and Responses:

# Operation 1: The system must receive, in real-time, raw LiDAR data from the sensor.

# Response 1: The system initializes real-time data processing.

# Operation 2: The system performs point cloud processing and obstacle recognition.

# Response 2: When an obstacle is detected within a user-defined safety zone, the system promptly triggers real-time auditory or haptic feedback to alert the user.

# Operation 3: The system continuously monitors and analyzes the LiDAR data stream.

# Response 3: The system maintains a real-time awareness of the user's surroundings, ensuring that potential obstacles are promptly recognized and communicated.

# Derived Function Requirement 2: Path Planning and Navigation

# Feature: Path Planning and Navigation

# Requirement Source: User

# Inputs and Stimulus:

# Inputs: User's destination input (coordinates or address)

# Stimulus: User-provided navigation requirements

# Sequence of Operations and Responses:

# Operation 1: The system receives the user's destination input.

# Response 1: The system initiates path planning and navigation processes.

# Operation 2: The system employs advanced routing algorithms, integrating user preferences, real-time obstacle data, and environmental conditions.

# Response 2: The system calculates an optimal navigation path that avoids detected obstacles and considers user preferences.

# Operation 3: The system provides step-by-step auditory or haptic directions to guide the user.

# Response 3: The system continuously updates and delivers navigation instructions to the user, adapting to real-time changes in the environment, including obstacle avoidance.

# Derived Performance Requirement 1: Obstacle Detection Accuracy

# Feature: Obstacle Detection Accuracy

# Requirement Source: Technical Specification

# Static Numerical Requirement: The system must detect obstacles with a minimum accuracy of 95% within a range of 5 meters.

# Dynamic Numerical Requirement: The system must update obstacle information and provide feedback to the user at a minimum rate of 10 updates per second. This ensures that real-time obstacle detection remains highly responsive.

# Derived Performance Requirement 2: User Localization

# Feature: User Localization

# Requirement Source: Technical Specification

# Static Numerical Requirement: The system should accurately determine the user's location within a margin of error not exceeding 1 meter.

# Dynamic Numerical Requirement: The system must continuously update the user's location with a frequency of at least 5 updates per second. This frequent updating ensures that the user's position is accurately tracked in real-time.

# Derived Interface Requirement 1: User Input

# Feature: User Input

# Requirement Source: User

# Source of Input or Destination of Output: The system should accept user destination inputs via a user-friendly interface, such as voice commands or a mobile application. This interface should support both manual input and voice recognition technologies for versatile user interaction.

# Derived Interface Requirement 2: Auditory/Haptic Feedback

# Feature: Auditory/Haptic Feedback

# Requirement Source: Stakeholder

# Source of Input or Destination of Output: The system should deliver auditory or haptic feedback to the user to convey information about obstacles, directions, and navigation. This includes providing clear, real-time auditory cues and haptic feedback through compatible wearable devices.

# Derived Logical, Database, and/or Reuse Requirement 1: Data Processing Logic

# Feature: Data Processing Logic

# Requirement Source: System Design

# Types of data and/or operations performed:

# The system's logic must incorporate advanced algorithms for real-time LiDAR data processing, including point cloud analysis and obstacle recognition.

# The logic should also include mapping and routing algorithms for path planning and real-time navigation.

# The system's logic should dynamically adjust feedback based on user preferences and environmental factors, making it versatile for users to navigate various environments.

# Derived Logical, Database, and/or Reuse Requirement 2: Database Management

# Feature: Database Management

# Requirement Source: System Design

# Types of data and/or operations performed:

# The database component should efficiently store LiDAR data, user profiles, user preferences, and historical environmental information.

# It must incorporate advanced data management techniques, including data indexing and compression, to ensure efficient storage and retrieval.

# The database should be designed to maintain data integrity, and it should constantly update with the latest environmental data for accurate and timely feedback to the user.

# Architecturally Significant Elements

# Overview and Architectural Views

* Overview
  + The product would ideally be a hat with a LIDAR sensor
  + The surroundings of the user would be mapped
  + Auditory alerts would be sent to the user via earpieces or headphones
    - Alerting them of objects nearby
* Architectural Views
  + System Engineering View
    - Breakdown of how the different hardware and software comes together
    - Breaks down the components that make up the entire system
  + Data Flow View
    - Deals with the capturing, processing, storing, and security of the data
    - Follows the flow of data throughout the system
  + Logical View
    - Focuses on the high level structure of the system
    - It delves into how the different components of the system interact
  + Process View
    - Focuses on the dynamic parts of the system
    - Focusing on how the different processes and tasks come together to produce the real time feedback
  + Development View
    - Describes the modular structure and organization of the system
    - Breaks down the development responsibilities of the developers, teams and components
  + Physical View
    - Looks at how all the physical components connect and work together
    - Components
      * LIDAR Sensor hat
      * Pressure Wristband
      * Mobile Application
      * Server Infrastructure
  1. **Logical/Quality Elements and why each is architecturally significant**
* Reliability
  + If the system is unreliable it could result in the user being injured
  + The user needs to be able to trust the product
* Usability
  + The product needs to be utilized by a blind person
  + The product should be simple and easy to use
* Portability
  + The product needs to be used out and about and on the go
  + The user needs to be able to use the product almost anywhere
  1. **Database Elements and why each is architecturally significant**
* LIDAR data points
  + Used to validate the data being collected
  + Make sure the system is working properly
  + Track movement to help navigate
  + Stored only for a short period of time
    - To not utilize enormous amounts of storage
  1. **Reuse Elements and why each is architecturally significant**
* Slamtec RPLIDAR A1 - 360 Laser Range Scanner (LIDAR)
* (<https://www.adafruit.com/product/4010#description>)
  + Range of 12 Meters 360 degrees
    - Allows for mapping of a good distance
    - Doesn’t map too far as to be irrelevant
  + 60 mm height x 98.5 height and weighs 170g
    - Relatively small and lightweight
    - Is not to cumbersome or obnoxiously big
  + $100
    - More affordably priced
  + Used to map the users surroundings
  + Used to calculate the distance of surrounding objects from user
* Earpiece/Headphones
  + Used to alert the user of their surroundings
* LidarView
* (<https://lidarview.kitware.com/>)
  + Used to process the data collected from the LIDAR
  + Open source
  + Free to Use
  + Can visualize the data in 3D
  + Can be combined with object detection and tracking
  + Can be used to analyze the data collected
* MySQL
  + Used as the systems database
  + Open Source
  + High performance
  + Helps provide data security

“SLAMTEC RPLIDAR A1 - 360 Laser Range Scanner.” Adafruit Industries Blog RSS, Adafruit, www.adafruit.com/product/4010#description. Accessed 25 Oct. 2023.

Lidarview.” Visualize and Process Live Captured 3D LiDAR Data in Real-Time, Kitware, lidarview.kitware.com/. Accessed 25 Oct. 2023.

**4. Draft Architecture**

**4.1 Architectural Views**

**4.1.1 Logical View**

The Logical View offers an in-depth understanding of the high-level structure of the Lidar System for Blind People. It delves into the organization of the system's components, modules, and their interactions, shedding light on how the system's logic is organized to deliver its core functionality.

**4.1.1.1 Components:**

* **Core Logic Module:** At the heart of the system is the Core Logic Module. This module acts as the central processing unit, orchestrating the various components, managing data flow, and overseeing the decision-making process. It is responsible for real-time obstacle detection, path planning, and user interaction.
* **User Interface Module:** The User Interface Module provides the means for visually impaired users to interact with the system. It supports multiple input modalities, including voice commands and tactile inputs, to ensure accessibility and user-friendliness.
* **Data Processing Module:** The Data Processing Module handles the raw data collected from the Lidar sensors and other sensors, conducting point cloud analysis and obstacle recognition. It plays a crucial role in transforming sensor data into meaningful information for users.
* **Mapping and Routing Module:** This module focuses on the path planning and navigation aspects of the system. It employs advanced routing algorithms, taking into account real-time obstacle data, user preferences, and environmental conditions to calculate optimal navigation paths.
* **Feedback Generation Module:** The Feedback Generation Module is responsible for translating the processed data into real-time auditory and haptic feedback. It customizes feedback based on user preferences and the detected environmental conditions.

**4.1.1.2 Interactions:**

* **User Interaction Flow:** The logical view outlines how a user interacts with the system. When a user initiates a voice command or provides tactile input, the User Interface Module captures the input and communicates it to the Core Logic Module. The Core Logic Module then interprets the user's intent and coordinates with the Data Processing and Mapping and Routing Modules to provide relevant feedback.
* **Data Processing Flow:** The flow of data is critical in this architecture. The ta Processing Module continuously receives raw sensor data from the Lidar and other sensors. It processes this data in real-time, identifying obstacles and environmental features. The Feedback Generation Module depends on the processed data to generate meaningful feedback for the user.
* **Customization and Adaptation:** The Logical View highlights how the system adapts to user preferences. The User Interface Module allows users to customize their interaction preferences, such as voice command styles and tactile feedback intensity. This customization is integrated into the Core Logic Module's decision-making process.
* **Synchronization and Real-time Awareness:** The view emphasizes the need for synchronization and real-time awareness. The Core Logic Module ensures that sensor data is synchronized, and the system maintains continuous awareness of the user's surroundings to provide timely and relevant feedback.

By providing this enhanced description of the Logical View, readers gain a comprehensive insight into the core components, their interactions, and the flow of data and user interactions within the Lidar System for Blind People. This clarity is essential for understanding the system's inner workings and how it fulfills the requirements and expectations of visually impaired users.

**4.1.2 Process View**

The Process View offers an in-depth exploration of the dynamic aspects of the Lidar System for Blind People. It emphasizes the processes, threads, or tasks that work together to execute the system's functions and deliver real-time feedback to visually impaired users.

**4.1.2.1 Processes:**

* **Data Acquisition Process:** This process manages the continuous acquisition of sensor data, including data from Lidar sensors, cameras, radar sensors, and microphones. It oversees the collection, synchronization, and buffering of raw sensor data streams.
* **Data Processing Process:** The Data Processing Process handles the real-time analysis of sensor data. It employs advanced algorithms for point cloud processing, obstacle recognition, and environment mapping, ensuring the system's ability to detect obstacles and provide accurate feedback.
* **User Interaction Process:** The User Interaction Process facilitates user input, including voice commands and tactile feedback preferences. It interprets user commands and coordinates with other processes to execute the desired actions.
* **Feedback Generation Process:** The Feedback Generation Process is responsible for translating processed data into real-time auditory and haptic feedback. It customizes the feedback based on user preferences and environmental conditions.
* **Navigation Process:** The Navigation Process calculates optimal navigation paths based on user destination inputs, obstacle data, and environmental conditions. It continuously updates and delivers step-by-step auditory or haptic directions to guide the user.

**4.1.2.2 Interactions:**

* **Data Flow and Coordination:** The Process View outlines the flow of data among these processes. Data acquired by the Data Acquisition Process is processed by the Data Processing Process. The User Interaction Process provides user input, influencing the Core Logic Module's decisions, which are then communicated to the Feedback Generation and Navigation Processes.
* **Real-time Processing:** Emphasized is the need for real-time processing. The Data Processing Process must analyze sensor data in real-time to detect obstacles promptly. The Feedback Generation Process generates feedback in real-time, ensuring users receive timely information.
* **Feedback Customization:** The view highlights the dynamic interaction between the User Interaction Process and the Feedback Generation Process. Users can customize their feedback preferences, influencing the feedback generated during navigation.
* **Continuous Navigation:** The Navigation Process ensures continuous, real-time updates to provide users with dynamic navigation instructions. It adapts to changing environmental conditions and obstacle data.

By providing this enhanced description of the Process View, readers gain a deeper understanding of the dynamic processes, their interactions, and the real-time nature of the Lidar System for Blind People. This view is crucial for grasping how the system operates and how it responds to user inputs and changing environmental conditions, ultimately enhancing the safety and independence of visually impaired users.

**4.1.3 Development View**

The Development View provides insights into the modular structure and organization of the Lidar System for Blind People, emphasizing how the development process is managed and coordinated. It details the division of responsibilities among developers, teams, and components, allowing for efficient and collaborative system development.

**4.1.3.1 Development Structure:**

* **Development Teams:** The development of the system is organized into specialized teams, each responsible for distinct aspects of the project. These teams include hardware development, software development, user interface design, and quality assurance.
* **Modular Development:** The system's architecture is designed to be modular, allowing different teams to focus on specific components. This modularity ensures that individual teams can work in parallel and facilitates easier integration.
* **Iterative Development:** The development process follows an iterative model, with regular feedback and testing cycles. This approach allows for continuous improvement, refinement, and the incorporation of user feedback.

**4.1.3.2 Responsibilities and Interactions:**

* **Hardware Development Team:** This team is responsible for the hardware components of the system, including the ring-like area scanner and the pressure bracelet. They collaborate closely with the software development team to ensure hardware-software compatibility.
* **Software Development Team:** The software development team focuses on the development of the system's core logic, data processing algorithms, user interface, and feedback generation. They work in coordination with the hardware team to enable seamless integration.
* **User Interface Design Team:** The user interface design team is dedicated to creating an accessible and user-friendly interface. They collaborate with the software development team to ensure that the user interface aligns with the needs of visually impaired users.
* **Quality Assurance Team:** The quality assurance team plays a critical role in testing and validating the system at various stages of development. They provide feedback to development teams, helping to identify and resolve issues.

**4.1.3.3 Collaboration and Integration:**

* **Team Collaboration:** The view underscores the importance of effective collaboration among teams. The hardware and software development teams collaborate to ensure the compatibility and functionality of the overall system.
* **Parallel Development:** The modular architecture allows different teams to work on their components simultaneously, enhancing efficiency and reducing development time.
* **Integration Points:** The Development View identifies key integration points where hardware and software components come together. This ensures that the system functions cohesively and that the hardware components are capable of supporting the software's requirements.

By providing this enhanced description of the Development View, readers gain a more comprehensive understanding of how the project is structured, how development responsibilities are divided, and how iterative and collaborative development approaches are employed to create the Lidar System for Blind People. This clarity is vital for successful project management and efficient development processes.

**4.1.4 Physical View**

The Physical View offers an in-depth exploration of the physical components and their relationships within the Lidar System for Blind People. It emphasizes the layout and interconnections of hardware components, providing insight into how the physical elements of the system come together.

**4.1.4.1 Physical Components:**

* **Ring-Like Area Scanner:** This component is a crucial part of the system's hardware. It includes Lidar sensors positioned to capture a 360-degree view of the user's surroundings in real-time. The scanner is designed to be compact and lightweight, ensuring it is comfortable to wear.
* **Pressure Bracelet:** The pressure bracelet is a wearable device equipped with an array of pressure points. These points correspond with directions and the intensity of sensed obstacles and features. The bracelet is designed for user comfort and ease of wear.
* **Mobile Application:** The system includes a dedicated mobile application designed for smartphones. This application serves as a user interface, facilitating system setup, customization, and providing additional information. It connects with the wearable hardware components to enhance the user experience.
* **Server Infrastructure:** Centralized server infrastructure plays a critical role in data synchronization, storage, and processing. It manages the efficient processing of real-time data and ensures that data is synchronized across users' wearable devices.

**4.1.4.2 Physical Interconnections:**

* **Wearable Integration:** The ring-like area scanner and the pressure bracelet are designed to work in close coordination. The scanner continuously captures data about the user's surroundings, and this data is processed and translated into pressure feedback on the bracelet to provide users with tactile information about obstacles and directions.
* **Mobile Application Interface:** The mobile application interfaces with the wearable hardware components. Users interact with the system through the mobile app, configuring settings, and receiving additional information about their environment.
* **Server Communication:** The wearable hardware components synchronize with the central server infrastructure. This connection ensures that real-time data is processed, and users receive timely feedback.

**4.1.4.3 Physical Layout:**

* **Compact and Wearable:** The physical view highlights that the hardware components, including the scanner and the pressure bracelet, are designed to be lightweight and compact, ensuring that users can comfortably wear them for extended periods.
* **User Mobility:** The physical layout emphasizes the portability of the hardware components. Users can use the system on the go, both indoors and outdoors, allowing them to navigate various environments with confidence.

By providing this enhanced description of the Physical View, readers gain a deeper understanding of the physical components of the system, their interconnections, and the focus on user comfort and mobility. This view is crucial for ensuring that the physical elements of the Lidar System for Blind People effectively serve visually impaired users.

**4.2 Logical / Quality Elements**

**4.2.1 Reliability**

Reliability is paramount in the Lidar System for Blind People, ensuring consistent, trustworthy operation crucial for user safety. It guarantees user trust in the system, fundamental for the visually impaired community.

* **User Trust:** The system's reliability directly impacts user trust. Users rely on the system's accuracy to make critical decisions about their surroundings, emphasizing the need for dependable performance.
* **Data Processing:** Advanced algorithms analyze real-time data, detecting obstacles, mapping, and routing. The reliability of these algorithms ensures accurate feedback to users, enhancing their situational awareness and safety.

In summary, reliability is pivotal, instilling confidence in users and enabling safe navigation. The system's robustness is foundational, ensuring consistent and dependable performance for visually impaired individuals.

**4.2.2 Usability**

Usability is a critical element in the Lidar System for Blind People, with a strong emphasis on simplicity for visually impaired users.

* **Accessibility:** Usability is paramount, particularly for visually impaired users. The interface is designed for straightforward navigation through tactile or voice commands, ensuring accessibility.
* **User-Centric Design:** Prioritizing user needs, the system's design places emphasis on user-friendly interactions, accommodating diverse environments and ensuring a seamless experience.

In summary, usability is central to the system's design, making it accessible and user-centric for visually impaired individuals, facilitating effective navigation and interaction.

**4.2.3 Portability**

Portability is a core feature in the Lidar System for Blind People, allowing users to navigate various environments with ease.

* **On-the-Go Usage:** The system is designed for easy portability, ensuring users can use it in different settings, both indoors and outdoors. It prioritizes user mobility, enabling confident navigation in diverse environments.

In summary, portability is integral to the system's design, promoting on-the-go usage and providing visually impaired users with the freedom to use the system almost anywhere.

**4.3 Database Elements**

**4.3.1 Data Storage**

Data storage in the Lidar System for Blind People is a fundamental architectural element that efficiently manages Lidar data, user profiles, and environmental information.

* **Database Structure:** The system incorporates a well-structured database that organizes Lidar data, user profiles, and historical environmental information. This structure is designed to support efficient data management, ensuring that the data is easily accessible and retrievable.
* **Data Cataloging:** To enhance efficiency, the database employs data indexing and compression techniques. Data indexing allows for quick retrieval of specific information, while compression reduces storage requirements, making the most of available resources.
* **Security Measures:** Data privacy and security are top priorities. The system implements robust security measures, including access controls and encryption, to safeguard sensitive user information. These measures ensure that user data, including location and personal information, is protected and compliant with relevant privacy regulations.

In summary, the system's data storage architecture is designed to efficiently manage a variety of data types, maintain data integrity, and ensure data security for the benefit of visually impaired users. It also emphasizes accessibility and privacy, enhancing the overall reliability and user trust in the system.

# 4.3.2 Data Processing Logic

Data processing logic in the Lidar System for Blind People is a critical architectural component responsible for real-time data analysis, including point cloud analysis, obstacle recognition, and routing algorithms.

* **Data Processing Modules:** The system comprises distinct data processing modules that handle specific tasks. These modules include point cloud analysis, obstacle recognition, and routing algorithms. Each module is responsible for a particular aspect of data analysis, enhancing the system's efficiency and responsiveness.
* **Algorithm Integration:** Advanced algorithms are seamlessly integrated into the system's architecture to facilitate real-time data processing. These algorithms play a key role in obstacle detection, mapping, and routing. Their integration ensures that the system can promptly provide accurate feedback to users, contributing to their safety and spatial awareness.
* **User Preferences**: The system's architectural design incorporates elements that adapt feedback based on user preferences and environmental factors. This adaptability allows users to customize their experience, making it versatile for various environments and personal preferences. It ensures that the system remains user-centric, enhancing usability and user satisfaction.

In summary, the data processing logic is a central architectural element that enables real-time data analysis, integrates advanced algorithms for accuracy, and prioritizes user customization and adaptability, all of which are essential for a robust and user-friendly Lidar System for Blind People.

**4.4 Reuse Elements**

The Lidar System for Blind People's architecture strategically incorporates reuse elements to optimize system development and performance. These elements enhance the system's functionality while maintaining cost-effectiveness.

**Leveraged Technologies:**

* **Slamtec RPLIDAR A1 - 360 Laser Range Scanner (LIDAR)**: The system employs this laser range scanner to capture a 360-degree view of the user's surroundings with a range of 12 meters. This component is compact, measuring 60 mm in height, 98.5 mm in width, and weighing 170g, making it small and lightweight. Its affordability, priced at $100, ensures cost-effectiveness. It allows for efficient mapping of the user's surroundings without being cumbersome, enabling precise distance calculations for objects near the user.
* **Earpiece/Headphones**: These audio output devices are used to alert the user to their surroundings. By leveraging existing earpiece or headphone technology, the system ensures that users receive clear and real-time auditory cues, enhancing their spatial awareness.
* LidarView: LidarView (https://lidarview.kitware.com/) is an open-source software tool used to process data collected from the LIDAR. It offers the capability to visualize data in 3D, making it invaluable for providing users with a comprehensive understanding of their environment. Additionally, LidarView can be combined with object detection and tracking, allowing the system to analyze the collected data efficiently.

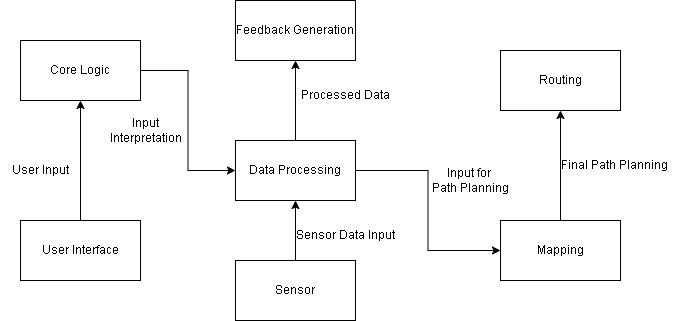
In summary, the Lidar System for Blind People's architecture optimally integrates reuse elements, ensuring system efficiency, affordability, and advanced functionalities. These elements are instrumental in providing visually impaired users with a reliable and cost-effective tool for enhancing their spatial awareness and safety.

# 4.5 Logical View

**4.5.1 Introduction and rationale for the view**

Architectural View 1 focuses on the integration of the ring-like area scanner within the Lidar System for Blind People. This view illustrates how the scanner collects environmental data and initiates the process of enhancing a visually impaired user's spatial awareness.

**4.5.2 Model / Graphical Representation**

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**4.5.3 Key Details**

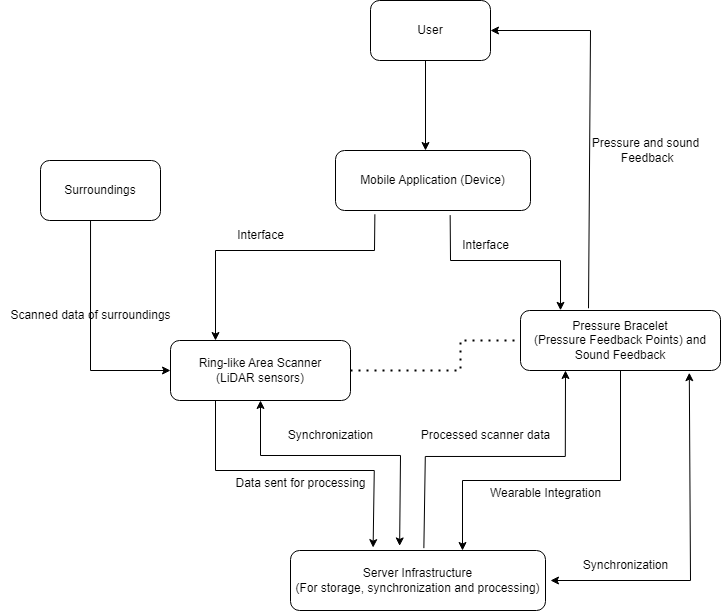
* It interfaces with the system's core logic to process Lidar data, identifying obstacles, landmarks, and spatial details.
* The scanner's data is continuously transmitted to the feedback mechanism for translation into pressure points on the bracelet, aiding the user in creating a mental map of their environment.
* Key performance indicators for this architectural view include the scanner's scanning accuracy, data transmission rate, and its ability to adapt to different environmental conditions.

# 4.6 Physical View

**4.6.1 Introduction and rationale for the view**

Physical view delves into the pressure bracelet, Mobile Device and Ring-like Area Scanner(LiDAR sensors) which are pivotal components in the Lidar System for Blind People. This view showcases how the bracelet receives data from the ring scanner and translates it into pressure feedback, enhancing the user's understanding of their surroundings.

**4.6.2 Model / Graphical Representation:**

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**4.6.3 Key Details**

* The ring-like area scanner is equipped with Lidar sensors, strategically positioned to capture a 360-degree view of the user's surroundings in real-time.
* The pressure bracelet is designed to provide tactile feedback to the user, utilizing an array of pressure points strategically placed to correspond with directions and intensity of sensed obstacles and features.
* It interfaces closely with the system's logic, receiving real-time data from the ring scanner, and translates this data into varying degrees of pressure, allowing the user to "feel" their environment.
* The pressure bracelet's design ensures comfort, wearability, and easy customization of feedback preferences to accommodate individual user needs.
* Key performance indicators for this architectural view include the accuracy of pressure feedback, the speed of response, and the adaptability of the bracelet to changing environmental conditions.
* The rationale for this view is to underscore the bracelet's role as the interface for user interaction and feedback. It empowers visually impaired individuals to navigate confidently, enhancing their spatial awareness and independence.
* The rationale behind this view is to highlight the crucial role of the ring scanner in gathering the raw data necessary for the system to provide meaningful feedback to the user, thereby facilitating safer and more confident navigation for the visually impaired.

*Lidar* (2023) *Wikipedia*. Available at: https://en.wikipedia.org/wiki/Lidar (Accessed: 25 October 2023).

# Initial Risk Analysis

# Overview

# Highest Priority Project Risk: Size/weight

* Size is an important factor because stakeholders who will be using it will have to wear the product.
* There is an inherent size and weight requirement that will limit how the technology is laid out and integrated into the product.
* This is a priority because the product will not be useful to the target demographic if it is too big and weighs them down. It is very important that the product is as compact as possible while maintaining the usefulness
* Brenden Martinez
* A prototype will mitigate the risk of the size because seeing how each of the components will interact with each other will help with how things are laid out to make the product smaller.
* Having the research of what components will need to be used and what other alternatives that will achieve the same results that could be smaller and lighter would be found in the process of creating a prototype.

# Second Highest Priority Project Risk: Useful Accuracy of information

* Usefulness of the collected information to a user could be a problem. If the information provided is too much or confusing to a user it will cause them to be unable to make an important decision that could put their life at risk, more so since they are visually impaired. Additionally, if there is too little information could cause the same problem causing someone to walk into a situation that could endanger them.
* Alexander Chittim
* A prototype will help with what information is collected from the system and from that could be weeded out based on how useful that information is to the user. So a prototype could help with deciding what and how information is displayed to a user in a real situation that can not be thought of or missed when theorizing about what information the product will output.

# Next Highest Priority Project Risk: Accessibility/Cost

* If the product that is produced can not be afforded by the target demographic then the number of units sold will be very low and not get the reach that is needed to make it profitable. There is a high risk that using lidar may be too expensive of a solution and that other more cost effective solutions are available that will still achieve the same results.
* Prathit Barot
* The research and potential building of a prototype will provide an estimated cost of a unit that will be produced that will cause the search for other alternative solutions for detecting people and objects around a visually impaired individual.

# Conclusion

**6.1 New or Updated Key Conclusion 1**

The Lidar System for Blind People has been meticulously designed to meet the unique needs of visually impaired users, providing them with a powerful tool for enhancing their spatial awareness and safety.

**6.1.1 Detail Item 1: Reliability and Trust**

* Reliability is paramount in ensuring user trust. The system's robust architecture and advanced algorithms guarantee consistent and trustworthy performance. Visually impaired users can rely on the system to make critical decisions about their surroundings, enhancing their independence.
* Data processing is a key component in achieving reliability. The real-time analysis of sensor data, accurate obstacle detection, and responsive feedback mechanisms are foundational for building user trust.

**6.1.2 Detail Item 2: Usability and Accessibility**

* Usability is a core feature of the system, with a strong emphasis on simplicity for visually impaired users. The user-centric design, intuitive interfaces, and support for multiple input modalities ensure that users can interact with the system with ease.
* Accessibility is a fundamental aspect of usability. The system's design accommodates diverse environments and provides visually impaired users with a seamless and accessible experience, enhancing their ability to navigate confidently.

**6.2 New or Updated Key Conclusion 2**

The architecture of the Lidar System for Blind People integrates various components and technologies to optimize performance, user experience, and cost-effectiveness.

**6.2.1 Detail Item 1: Reuse Elements**

* Leveraging technologies such as the Slamtec RPLIDAR A1 and open-source software like LidarView enhances the system's functionality while maintaining cost-effectiveness. These elements enable efficient mapping, real-time data processing, and advanced visualization, contributing to the system's effectiveness.
* By incorporating existing earpiece/headphone technology for auditory alerts, the system ensures clear and real-time feedback to users about their surroundings. This reuse of established technology simplifies user adoption and enhances the user experience.

**6.3 Items for Future Consideration**

As the Lidar System for Blind People continues to evolve, there are several aspects that merit future consideration:

* Integration with Emerging Technologies: The system should explore opportunities to integrate emerging technologies such as 5G connectivity, edge computing, and AI-driven object recognition to further enhance its capabilities and real-time responsiveness.
* User Feedback and Continuous Improvement: Establishing a robust feedback mechanism from visually impaired users and continuously improving the system based on their input is essential. This ongoing feedback loop will ensure that the system evolves in line with the evolving needs and preferences of its users.
* Regulatory Compliance: Given the sensitive nature of user data, continuous monitoring of data privacy and security regulations is vital. Staying up-to-date with evolving privacy laws and regulations and proactively adapting the system to remain compliant is a crucial consideration.

In conclusion, the Lidar System for Blind People represents a significant advancement in assistive technology, providing visually impaired users with a reliable, accessible, and portable tool for enhanced mobility and safety. As technology continues to progress, the system is well-positioned to adapt and grow, meeting the evolving needs of its users.

# Appendix A: Credit Sheet

| Team Member Name | Contributions |
| --- | --- |
| Monil Prajapati | * Section 1) Received Requirement * Physical View Diagram in setion 4) Draft Architecture * Reviewed section 2 and 4. |
| Alexander Chittim | * Section 3) Architecturally Significant Elements |
| Prathit Barot | * Section 2) Derived requirements. * Reviewed section 1 and section 3. * Research on different relevant hardware and software. * Analysis on received required and finding minimum threshold of different functionalities. |
| Brenden Martinez | * Section 5: Initial risks * Reviewed Sections 3 and 4 |
| Parv Tejas Shah | * Section 4 Draft Architecture |