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SmartCane+

A Modular Device for Transforming Traditional Canes into Advanced Mobility Aids for the Elderly.

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Abstract

The "SmartCane+" thesis abstract outlines an initiative aimed at improving conventional walking canes into more intelligent, helpful devices for senior citizens. The incorporation of microcontrollers, which permits wireless communication and connection functions, is the primary innovation. With the use of MIT App Inventor, a unique mobile application and this technology, the cane can send its position to the user using Bluetooth. Because it can stop the cane from becoming lost, which is a regular problem for senior users, this function is especially beneficial.

The SmartCane+ design places a strong focus on accessibility and cost. The idea maintains cheaper prices and simpler technology by choosing not to add complex hardware, which makes it easier for consumers to embrace and operate without feeling overwhelmed by complexity. By striking a mix between cutting-edge technology and intuitive operation, the design hopes to keep the cane a help rather than a burden.

The results of the project indicate that the SmartCane+ effectively improves the safety and independence of senior users by ensuring the cane remains within a reachable distance and providing timely alerts. Testing showed reliable performance in various environments, although closed spaces introduced more variability. Future work will focus on enhancing the system's accuracy, optimizing power consumption, and expanding compatibility with other mobile platforms.

Keywords: Assistive Technology, MIT App Inventor, Microcontrollers, Elderly Mobility, Wireless Communication, Power Management.

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Yours sincerely,

Narreddy Nishwanth Reddy
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Chapter 1

Introduction

The cane, a simple yet crucial tool, has served humanity for centuries. Throughout history, it has provided support and stability to people with mobility issues. In ancient times, canes were often symbols of authority or wisdom, used by rulers and elders alike. Their practicality and symbolism have made them iconic across cultures. In many societies, canes have been elaborately crafted, sometimes incorporating intricate designs or valuable materials to reflect the status of their owners. Over time, canes have evolved from being mere walking sticks to more sophisticated devices, yet their core purpose remains unchanged: to offer assistance and enhance mobility.

As our understanding of health and mobility issues has evolved, so has our approach to designing canes. The traditional cane, often made of wood or metal, has become a staple for the elderly and those with disabilities. Modern designs have introduced ergonomic handles, adjustable lengths, and lightweight materials to improve usability. Despite these advancements, a persistent challenge remains ensuring the cane is always within reach when needed. This problem has prompted the exploration of new technological solutions to address the needs of cane users more effectively.

The humble cane has not only been a tool for mobility but also a companion, offering individuals the ability to maintain their independence. Over the centuries, it has been utilized by a diverse range of people, from everyday individuals seeking assistance in their daily movements to distinguished figures such as kings, clergy, and intellectuals who used canes as symbols of status and authority. The use of canes spans across many cultures and time periods, illustrating their universal importance. These walking aids have been adapted to suit different needs and environments, demonstrating remarkable resilience as a design concept.

1.1 Background

In recent years, the integration of smart technologies into everyday objects has opened up new possibilities for innovation. The ESP32-C3 microcontroller, a powerful yet compact device, offers wireless connectivity and processing capabilities suitable for creating smart canes. Coupled with the MIT App Inventor, which provides a user-friendly platform for designing custom mobile applications, these technologies can transform a traditional cane into an intelligent assistant.

MIT App Inventor allows developers to create custom mobile applications with minimal coding experience, using a visual programming interface. This approach leverages MIT App Inventor to design an app that interfaces with the ESP32-C3 microcontroller via Bluetooth, providing a scalable and customizable platform for developing smart cane solutions that cater to the specific needs of users.

The ESP32-C3 microcontroller is an excellent choice for this purpose due to its compact size, integrated Wi-Fi and Bluetooth capabilities, and low power consumption. It serves as the core of the smart modular device for the cane, with MIT App Inventor enabling the creation of custom interfaces that allow users to receive alerts and interact with their smart cane through their smartphones or other devices.

The scope of this thesis revolves around the development of SmartCane+, a modular device that transforms traditional canes into economically feasible smart mobility aids for the elderly, focusing primarily on the integration of wireless connectivity features without the inclusion of physical sensors. Situated within the domains of electrical engineering and geriatric care, the project emphasizes the practical application of technology in enhancing elderly care.

The thesis will explore technical specifications, design processes, implementation strategies, and testing outcomes, with a special emphasis on user interface enhancements and the use of connectivity to alert users about the cane's location. By avoiding the use of sensors, the project prioritizes economic feasibility, ensuring the solution remains affordable and accessible. The exclusion of broad technological explorations and in-depth medical analyses helps maintain a focused investigation, allowing for a thorough and meaningful examination of SmartCane+ as a significant, cost-effective innovation in elderly assistive technology.

1.2 Scope of the Thesis

The primary focus is on integrating wireless connectivity features without the inclusion of physical sensors to ensure affordability and ease of use. The scope includes the following key areas:

- **Design and Development of the Modular Device:**
  - Utilizing the Arduino Nano 33 IOT and ESP32-C3 Devkit microcontrollers to enable wireless communication and connectivity features.
  - Ensuring the device is compact, energy-efficient, and capable of extended use without frequent recharges.
- **Mobile Application Development:**
  - Creating a mobile application using MIT App Inventor to interface with the smart cane.
  - Enabling the application to send alerts via Bluetooth, enhancing the usability and functionality of the cane.

- **Economic Feasibility and Accessibility:**
  - Prioritizing cost-effectiveness by avoiding the use of physical sensors, thereby maintaining lower costs and simplifying the technology for easier adoption by elderly users.
  - Ensuring the device remains user-friendly and does not overwhelm users with complexity.
- **Usability and Power Management:**
  - Implementing an economical and sustainable approach to power management to ensure the device is energy-efficient and can be used for extended periods without frequent recharges.
  - Focusing on practical usability features that enhance the daily lives of senior citizens.

1.3 Outline

The thesis is structured as follows:

- **Chapter 1 (Introduction):**
  - Background on the use of canes among the elderly.
  - The necessity for technological enhancement in traditional canes.
- **Chapter 2 (Related Work):**
  - History and evolution of canes as mobility aids.
  - Review of related technologies in elderly care.
  - Current technologies in smart canes.
- **Chapter 3 (Problem statement, Objectives and Main contribution):**
  - The key mobility challenges faced by senior citizens and the project's response.
  - Key questions guiding the technological and design choices in SmartCane+.
  - Major goals of the project, including the development of a reliable alert system and a user-friendly mobile application.
- **Chapter 4 (Theory):**
  - Introducing Bluetooth technology and RSSI technology.
  - Statistical formulas for mean and deviation.
- **Chapter 5 (Methodology):**
  - Exploration of various technological solutions like RFID, GPS, and Wi-Fi based methods.

  - Justification for selecting Bluetooth Low Energy (BLE) and specific software and hardware configurations.
  - Assessment of platforms like Android Studio and Blynk, and reasons for choosing MIT App Inventor.

- **Chapter 6 (System Design and Implementation):**
  - Description of how the smart cane is designed to integrate and utilize the ESP32-C3 and MIT App Inventor technologies.
  - Detailed overview of hardware setups, including configurations for ESP32-C3 DevKit and Arduino Nano 33 IoT.
  - Insights into the development of firmware and the mobile application using MIT App Inventor.

- **Chapter 7 (Results and Analysis):**
  - Analysis of Microcontrollers performance with different smartphones.
  - Comparative performance of two microcontrollers.
  - Effects of different settings on sensor accuracy.

- **Chapter 8 (Validation):**
  - Data measurements like deviation and mean across environments were calculated.
  - Issues encountered and potential improvements.
  - Effects of findings on the practical use of SmartCane+ among the elderly.

- **Chapter 9 (Discussion):**
  - Research Questions answered.
  - Comparing results with other works.
  - Limitations.

- **Chapter 10 (Conclusion and Future Work):**
  - Recap of the project's contributions to enhancing traditional canes.
  - Assessment of the device's success based on testing and feedback.
  - Recommendations for future research and development to enhance device functionality.

1.4 Ethical, societal and sustainability aspects

1.4.1 Ethical Considerations

- **Privacy and Data Security:** As the SmartCane+ integrates technology that may collect, store, and transmit user data, ensuring the privacy and security of this data is paramount. The device will adhere to relevant data protection laws such as GDPR. Users must be fully informed about what data is collected, how it is used, and who has access to it, and must give their consent before any data collection begins.

1.4.2 Societal Implications

- **Social Inclusion:** This thesis explores the enhancement of mobility aids with smart technology, potentially increasing independence and safety for elderly and visually impaired individuals

1.4.3 Sustainability Aspects

- **Energy Efficiency:** The SmartCane+ will be designed for energy efficiency, including the use of long-life rechargeable batteries and energy-saving modes to reduce power consumption and minimize the environmental footprint.

Chapter 2

Related Work

This chapter presents a comprehensive analysis of existing technologies and research on the creation of mobility aids, specifically smart canes, in order to contextualize the SmartCane+ project's innovation and accomplishments.

2.1 Background Knowledge

Understanding the care and support needs of older people: a scoping review and categorisation using the WHO international classification of functioning, disability and health framework" by S. Abdi et al. In the development of our thesis project, we drew upon critical insights into the escalating challenges within the UK's formal and informal care systems. Notably, the rising number of older individuals with unmet care and support needs highlights a significant public health concern. This awareness informed the foundational background of my research, emphasizing the urgency to explore effective solutions tailored to the evolving needs of the elderly population. Addressing these needs is imperative, and a thorough understanding of the specific care and support requirements of older people is essential to devising appropriate interventions. This paper provides a comprehensive review of the care and support needs of elderly people, using the WHO's classification framework. It offers insights into the physical, social, and psychological challenges faced by the elderly. relevance of this research paper is to Understand these needs can help tailor the SmartCane+ features to better support elderly users in their daily lives [12].

Insights into Older Adults' Technology Acceptance through Meta-Analysis This article reviews existing research on how older adults accept and use technology, identifying key factors that influence their acceptance.These results are endorsed by studies showing how adoption rates for these technologies by older adults is much lower in this age range compared to other population groups (Anderson and Perrin, 2017;Vaportzis et al., 2017). Older adults also seem to be unfamiliar with medical and health-care-related technologies (Ma et al., 2021), a significant field for improving their quality of life. In terms of uses, research shows that social connection (staying in contact with friends and family) is one of the main reasons for using technology (Tsai et al., 2015;Wilson et al., 2021), even more so during the lockdowns in most Western countries caused by the COVID-19 pandemic. Insights from this paper could guide how we can introduce SmartCane+ to its intended users and how to overcome potential resistance due to technology integration [19].

Incorporating Usability Engineering into Assistive Technology Development for Older Adults, the importance of usability engineering in the development of assistive technologies for the elderly, emphasizing user-centered design and iterative testing. It provides methodologies and design considerations that could be crucial in developing the user interface for the SmartCane+ app and the overall usability of the cane [20].

In our exploration of localization techniques within Wireless Sensor Networks (WSNs), significant insights have been gleaned from existing research that utilizes the Received Signal Strength Indicator (RSSI). A pivotal study we reviewed involves detailed experimentation across three large WSNs, each network encompassing up to 250 nodes. This research extensively investigates the practical application of RSSI as a distance metric, leveraging the inherent environmental and topological characteristics of each network to assess accuracy and reliability.

The findings of the study underscore the intrinsic limitations of RSSI for distance measurement. Despite theoretical models that suggest a straightforward correlation between RSSI values and physical distance, real-world applications often experience substantial errors. These inaccuracies stem from diverse factors such as path-loss, fading, and shadowing effects, which are prevalent in dynamic radio environments.

Moreover, the research tested the effectiveness of the Spring-Relaxation algorithm in a collaborative localization protocol, aiming to enhance the precision of RSSI-based distance estimates. Contrary to initial expectations, the algorithm was unable to compensate for the measurement errors associated with RSSI. This revelation is critical, as it not only highlights the challenges of relying on RSSI for precise localization in WSNs but also points to the necessity for further development or alternative approaches in the field.

This study serves as a foundational element in understanding the complexities and constraints of RSSI-based localization, informing the ongoing development of more robust and accurate technologies in wireless sensor networking [17].

IoT Application Development Using MIT App Inventor to Collect and Analyze Sensor Data ,the study elaborates on integrating IoT capabilities with mobile app development through the use of MIT App Inventor and Android Things. This integration simplifies the creation of IoT applications by enabling developers to use visual programming environments to control and interact with hardware devices. The research highlights how MIT App Inventor, an open-source platform, makes it feasible for users with minimal coding experience to develop functional applications, thereby democratizing mobile app development. Android Things extends this accessibility to IoT devices, allowing applications to directly interact with hardware sensors like temperature sensors through simple block-based programming.

The study demonstrates the practical application of this technology through a workshop that teaches first-year students to create IoT applications, like a temperature monitoring system. This system uses sensors connected to an Android Things board to monitor environmental temperatures and provides real-time feedback to a mobile app, which adjusts its display color based on predefined temperature thresholds. The paper underscores the potential of this integration to foster innovative solutions in IoT and make technology more accessible to a broader audience. The successful implementation of these technologies can inspire a new generation of developers to engage in creating practical, data-driven solutions for everyday problems [21].

2.2 Existing works

This chapter outlines existing works that are relevant to the development of the SmartCane+ project. The related works aim to solve similar problems or utilize comparable technological approaches, providing context and grounding for our own development.

CCNY Smart Cane, developed at The City College of New York, this cane features Google Tango-based software and uses SLAM technology for indoor path planning and navigation. Users interact through a control panel on the cane, receiving directions via haptic feedback to ensure a safe path to set waypoints. The CCNY Smart Cane is similar to SmartCane+ in its goal to enhance mobility for visually impaired users. However, SmartCane+ extends this by focusing on elderly users with general mobility issues, adding modularity to existing canes, and incorporating a simpler, more intuitive alert system rather than comprehensive navigation aids [15].

Smart cane with range notification for blind people, a research from CYBER introduces a cane equipped with an ultrasonic sensor for distance measurement, designed to prevent injury from falls by alerting blind users to obstacles through audio alerts.Blind people are prone to sweep or knock whatever obstacle which pass before them during walking, subjecting them to risk of injury caused from fall.

The aim of this project is to develop a smart cane with distance measurement system. The system comprise of an ultrasonic sensor as input and earphone as the output. Ultrasonic sensor is used to measure distance from the obstacle. Data is then sent to National Instrument myRIO-1900 controller for processing which later produce beeping sound as the output. The process was graphically programmed using LabVIEW with FPGA as the intended target. Performance of the system has been ascertained through several verification tests. In general, the device will alert blind people of the obstacles through the audio output.

While this cane focuses on blind users and utilizes ultrasonic sensors for obstacle detection, SmartCane+ aims to benefit a broader demographic by using smartphone connectivity for more personalized alerts and settings configuration [24].

Research on Elderly Technology Familiarity, by Z. Roupa et al. investigates the familiarity of elderly individuals with modern technology, identifying barriers and facilitators in technology adoption.This research underpins the user experience design of SmartCane+.Older adults have a difficult relationship with technology mostly because hardware and software have not been designed to suit them. For a large part of the old population, technology is unfamiliar and "alien" and even when elderly people perceive the potential of technology, they consider the investment of personal resources needed to use a new artefact as too high. The language spoken by technology is unfamiliar to elderly people because it depends on a series of elements that are out of their culture. In the present paper we propose a design approach based on familiarity, investigating how to translate technology language into a language familiar to those individuals grown up before the technological revolution. Understanding the technology familiarity among elderly users helps tailor the smartphone application and cane design to ensure they are user-friendly and effectively meet the users need [23].

Chapter 3

Problem Statement, Objectives, and Main Contribution

3.1 Problem Statement

There are multiple other technologies, such as airtags, however they are not suitable for this application. For example, AirTags lack the tailored alerting mechanisms required for a cane-specific application that requires quick proximity alerts. Furthermore, we require third-party apps to do so, which are more expensive due to the monthly subscription. The loss of mobility aids such as canes poses a significant challenge for various user groups, notably the elderly and visually impaired. Elderly individuals often misplace their canes due to forgetfulness, while visually impaired users face the risk of theft without immediate detection. The primary concern is the inability to track the cane's proximity effectively, leading to potential inconvenience, distress, or danger for the user. Therefore, there is a critical need to develop a reliable tracking system that can alert users in real-time when their cane moves beyond a pre-set distance threshold. This project aims to create an innovative tracking tag specifically designed for integration with a cane, enhancing security and peace of mind for users dependent on these essential mobility aids.

In order to overcome these obstacles, this thesis created SmartCane+, a modular gadget that combines an ESP32-C3 microcontroller with a specially created mobile application created with MIT App Inventor. With its effective power management and dependable Bluetooth-based notifications, this smart cane seeks to improve user safety and independence without the need for pricey sensors. Through an emphasis on financial viability and with its user-friendly design, SmartCane+ seeks to improve senior citizens' general autonomy and well-being by offering an easily-acquired, useful mobility support option.

3.1.1 Research Question

1. **In what ways can the ESP32-C3 microcontroller be utilized to provide reliable wireless connectivity for a smart cane?**

   Motivation: The ESP32-C3 microcontroller is a small device that can handle wireless communications like Bluetooth. The reason we are focusing on this is to make sure the smart cane stays connected to other devices like smartphones. This helps keep the cane and its user safe, making sure they can always communicate without interruptions.

2. **How can the MIT App Inventor be employed to create a user-friendly mobile application that interfaces with the smart cane?**

   Motivation: MIT App Inventor is a tool that makes it easy to create apps, especially for people who are not expert programmers. We want to use it to make a simple and easy-to-use app that connects with the smart cane. This way, users, especially older adults, can easily use their cane's features without feeling overwhelmed by technology.

3.2 Aim

The primary aim of the thesis is to develop "SmartCane+", a modular device that transforms traditional canes into economically feasible smart mobility aids for the elderly. The focus is on integrating wireless connectivity features without the inclusion of physical sensors to ensure the solution remains affordable and accessible.

3.3 Objectives

The major goal of this thesis is to create SmartCane+, a modular device that adds enhanced functionality to traditional walking canes via the ESP32-C3 microcontroller and MIT App Inventor. The project's goal is to create and deploy a dependable Bluetooth-based alert system that warns users when their cane is outside of a predetermined range. Furthermore, creating a user-friendly mobile application with MIT App Inventor is a critical goal for assuring seamless interaction with the smart cane. Integrating the Adafruit LiIon or LiPoly Charger BFF Add-On for QT Py will result in efficient power management.

SmartCane+ will undergo extensive testing and evaluation in real-world scenarios to ensure user safety, comfort, and happiness. The concept also emphasises preserving economic feasibility and accessibility.The initiative also focuses on maintaining economic feasibility and accessibility, making SmartCane+ affordable to a diverse spectrum of older consumers. These objectives, taken together, seek to effectively improve geriatric mobility and independence.

3.4 Main Contribution

- **Development of SmartCane+:** The development of a modular smart cane that incorporates the ESP32-C3 microprocessor, improving traditional walking canes with improved functionality for older users.
- **Bluetooth-Based Alert System:** Significantly increasing user safety is the installation of a dependable Bluetooth-based warning system that alerts users when their cane travels beyond of a predetermined range.
- **User-Friendly Mobile Application:** Design and development of a custom mobile application using MIT App Inventor, providing an intuitive interface for seamless interaction with the smart cane.

Chapter 4

Theory

4.1 Bluetooth Technology

Bluetooth is a wireless communication protocol that uses radio waves in the ISM band, which is between 2.402 GHz and 2.480 GHz, to communicate data over short distances. It makes it easier to create highly secure Personal Area Networks (PANs). The Bluetooth Special Interest Group (SIG) developed this technology, which is widely used in many gadgets, including computers, smartphones, and other electronic devices, to exchange data or connect peripherals like keyboards and headphones without the need for physical connections [10].

4.2 RSSI

In a wireless communication system, the Received Signal Strength Indicator, or RSSI, is a metric used to evaluate the power level that a receiving device is receiving from the transmitting device. The signal strength is indicated by the RSSI, which is commonly expressed in decibels (0 dB) ranging from zero to a negative value. The strength of the signal received increases as the value approaches zero. It's crucial to remember that RSSI is a relative index rather than a precise milliwatt measurement of power. Rather, it offers a measure by which the signal strengths obtained from various devices on the same scale may be contrasted [13].

4.2.1 Using RSSI Distance Measurement

The Received Signal Strength Indicator (RSSI), which measures the power of received radio signals, is used to calculate the distance between wireless devices. The idea behind RSSI-based distance measuring is that as one moves farther away, signal strength drops logarithmically. Approximating the distance between devices can be done by calibrating the expected RSSI values at established distances. Signal accuracy, however, can be impacted by things like obstructions and environmental interference. Therefore, even while RSSI offers a helpful proximity gauge, its accuracy for measuring specific distances can vary, requiring improvements or tweaks to improve accuracy in real-world applications [14].

4.3 Statistical Formulas

Mean

The formula to calculate the mean of a dataset is given by:

$$\text{Mean} = \frac{\sum_{i=1}^{n} x_i}{n} \tag{4.1}$$

Where:

- x_i represents each value in the dataset.
- n is the total number of values in the dataset [9].

Deviation

The formula for deviation is given by:

$$MD = \frac{1}{n} \sum_{i=1}^{n} |x_i - \overline{x}| \tag{4.2}$$

where x_i are the data points, $\overline{x}$ is the mean of the data points, and n is the number of data points [8].

4.3.1 Explanation for the Need of Mean and Deviation

The mean and deviation are crucial statistical measures used to evaluate the SmartCane+ system's performance and reliability. The mean provides an average value of the RSSI readings or distance measurements, establishing a basic performance metric. This helps determine if the system performs within acceptable limits.

Deviation measures the variability from the mean, indicating the consistency of the system's performance. A low deviation suggests reliable and consistent measurements, while a high deviation indicates greater variability and potential reliability issues. Together, these metrics ensure a comprehensive understanding of the system's accuracy and consistency under various conditions.

Chapter 5

Methodology

In developing the smart cane system, multiple approaches were considered to achieve the optimal integration of technology with everyday mobility aids. This chapter outlines the various methodologies explored during the project's planning phase and details the rationale behind the selected approach, emphasizing how it aligns with the project's objectives.

5.1 Methodological Approaches Considered

The project considered several technological solutions and frameworks to enhance a traditional cane. These included:

- **RFID Tagging:** Using RFID technology to trigger alerts when the cane is a certain distance from a reader installed in the user's home or office [7].
- **GPS Tracking:** Incorporating GPS to provide real-time location tracking of the cane, useful for recovery if lost or stolen [3].
- **Wi-Fi-based Methods:** Utilizing Wi-Fi signals for indoor positioning and proximity alerts, though more suited to environments with extensive Wi-Fi coverage.

Each of these methods was evaluated for its feasibility, cost, ease of implementation, and the level of intrusion into the user's daily life.

5.1.1 Motivation:

In developing a tracking system for canes, we assessed RFID, GPS, and Wi-Fi, each showing significant limitations. RFID's short range and the high cost of active systems make it impractical. GPS, while precise, consumes too much power and performs poorly indoors. Wi-Fi, reliant on extensive infrastructure, lacks consistent accuracy. Thus, our project adopts Bluetooth Low Energy (BLE) technology, offering a low-power, adequately ranged solution compatible with modern mobile devices. BLE enables real-time proximity alerts, making it practical and user-friendly for individuals reliant on canes. This methodology provides a seamless and effective tracking system, integrating effortlessly into the daily activities of users.

5.2 Chosen Methodology

The methodology selected involves using the ESP32-C3 DevKit for its Bluetooth capabilities, coupled with smartphone notifications to alert users when their cane is out of a

preset range and send a vibration for 10 seconds. This choice was motivated by several key factors:

- **Low Energy Consumption:** Bluetooth Low Energy (BLE) offers a balance between range and power consumption, making it ideal for portable, battery-operated devices like a smart cane.
- **Ease of Implementation:** BLE is well-supported by many development platforms, including the Arduino and MIT App Inventor, facilitating rapid development and testing.
- **User Experience:** This method minimizes the need for user interaction, maintaining the traditional usability of the cane while enhancing it with smart capabilities without overwhelming the user with complex features.

5.3 Alternative Software Platforms Considered

In the development of the smart cane system, other software platforms such as Android Studio and Blynk were evaluated alongside MIT App Inventor. Each platform offered distinct capabilities and potential advantages; however, they were ultimately not chosen for specific reasons aligned with the project's objectives and constraints [5].

5.3.1 Android Studio:

Android Studio is a robust development environment for creating Android applications, offering extensive customization options and powerful tools for professional developers. While Android Studio provides greater flexibility and the ability to create more complex functionalities, it also demands a higher level of programming skill and a longer development time. The complexity of setting up and maintaining an Android Studio project would have increased the project's timeline and required more specialized knowledge in Android SDK and Java or Kotlin programming languages. Additionally, Android Studio projects can be more challenging to debug and optimize for different device types and versions of Android, potentially limiting the accessibility and user-friendliness of the end product [1].

5.3.2 Blynk:

Blynk is another platform that was considered, particularly for its user-friendly interface for building IoT applications. It allows developers to quickly build prototypes by providing a digital dashboard where you can connect various components and control them remotely. Although Blynk is excellent for rapid prototyping and supports various hardware modules including ESP32, it relies heavily on its own server infrastructure. This dependency could pose potential issues with latency, privacy, and long-term viability, should the platform's service conditions change. Moreover, Blynk typically requires a subscription for full functionality, which could impose additional long-term costs.Yet another reason why Blynk is not ideal for the project, "WiFi, cellular, USB, and Ethernet are supported by Blynk IoT. Classic Bluetooth and low energy Bluetooth (BLE) are not currently supported".This is the statement released by Blynk after the updtate which clearly states that Bluetooth is not supported [11].

5.3.3 Rationale for Not Using Android Studio and Blynk:

The decision to use MIT App Inventor over Android Studio and Blynk was driven by several factors:

- **Simplicity and Speed:** MIT App Inventor provides a more straightforward approach for creating functional applications quickly, without the need for extensive coding knowledge, making it ideal for academic projects where time and resources are limited.

- **Cost-Effectiveness:** Unlike Blynk, MIT App Inventor is completely free and does not require any subscription, reducing the cost implications for the project.

- **Educational Value:** MIT App Inventor offers educational resources that are particularly beneficial in an academic setting, helping students learn basic programming concepts and logical thinking in a visually intuitive environment.

- **Accessibility:** Applications developed with MIT App Inventor can be easily shared and used across different devices, ensuring that the end product is accessible to a wider audience without compatibility issues.

These considerations led to the selection of MIT App Inventor as the most suitable platform for developing the smartphone application component of the smart cane system.

5.4 Motivation for Selecting Two Different Mobiles

We chose the Oppo A16k and Samsung S22 Ultra as representative models for our tests to examine how the tracking system performs across different tiers of smartphone hardware. The Oppo A16k, being a more budget-friendly option, allows us to assess the system's performance on devices with potentially lower processing power and less sophisticated Bluetooth hardware. On the other hand, the Samsung S22 Ultra is a high-end device known for its advanced technological features, including superior connectivity options. By testing on both, we aim to ensure that our system is effective across a broad spectrum of mobile devices, verifying that the accuracy of the tracking system does not depend heavily on the mobile device's quality.

5.5 Motivation for Selecting Two Different Microcontrollers

For the microcontrollers, we selected the ESP32-C3 DevKit and the Arduino Nano 33 IoT to cater to different levels of computational abilities and integration features.

The **ESP32-C3 DevKit** is known for its precise readings and robust performance in handling multiple connections, which makes it ideal for validating the accuracy of our tracking system under various conditions. Its high-performance levels are crucial for implementing complex algorithms needed for precise distance estimation and reliable communication.

The Arduino Nano 33 IoT is included as a more accessible and widely used platform, which allows us to test the system's scalability and adaptability. This microcontroller, while less powerful than the ESP32-C3, is sufficient for simpler tracking implementations and is popular in educational and DIY projects, making it relevant for our audience.

By using these specific devices, we aim to thoroughly test our system's performance across different hardware specifications, ensuring that our solution is robust, adaptable, and scalable.

5.6 Motivation for Testing Two Different Environments

Our experimental setup is designed to validate the functionality and reliability of the tracking system in both open and closed environments. An **"open environment"** refers to spaces without physical obstructions that might interfere with signal transmission, such as a large hall or outdoor areas. A **"closed environment"** implies conditions where walls, furniture, or other structures could impact signal strength and quality, like inside a home or office.

The experiments will measure the RSSI (Received Signal Strength Indicator) values at various distances: at the source (0 m), at a threshold distance where alerts should trigger (approximately 50 as rssi strength), and at 1 meter to test signal strength consistency and range. These distances help us understand the effective range and reliability of the RSSI signal under different environmental conditions, providing empirical data to refine our system.

Chapter 6

System Design and Implementation

This chapter explains how we developed the system and how its hardware and software implementations work, along with the solution to the issue statement.

6.1 System Design

This project seeks to improve the functionality of a traditional cane by incorporating a smart device that alerts the user via tactile feedback (vibration) and visual notifications on their smartphone when the connection between the cane and the phone weakens, indicating potential misplacement or theft.

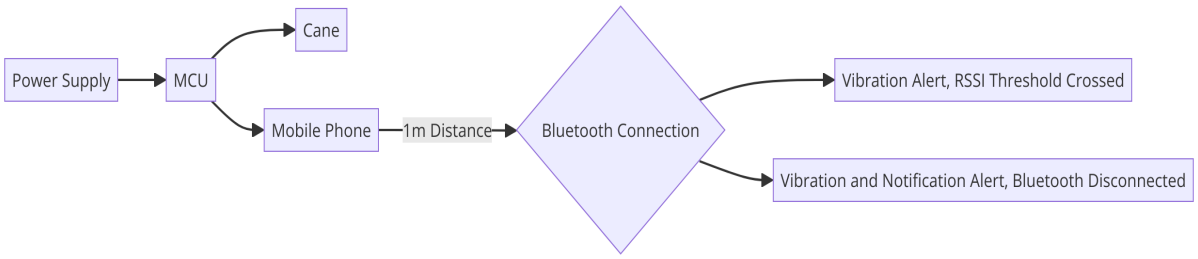

Figure 6.1: System Design

The SmartCane+ system design flowchart begins with the "Power Supply," which connects to the "MCU" (Microcontroller Unit). The MCU is linked to two main components: the "Cane" and the "Mobile Phone." The Mobile Phone establishes a "Bluetooth Connection" with the cane, indicated by an arrow labeled "1m Distance." Depending on the status of this Bluetooth connection, two alert mechanisms are activated: a "Vibration Alert" if the RSSI (Received Signal Strength Indicator) threshold is crossed, and a "Vibration and Notification Alert" if the Bluetooth connection is disconnected. Figure 6.1 illustrates the flow and interactions between these components and alerts within the SmartCane+ system.

6.1.1 Key Points

- **ESP32-C3 DevKit (from Olimex):** Serves as the central processing unit, managing Bluetooth communications and signal strength monitoring [2].
- **Arduino Nano 33 IoT:** An alternative microcontroller tested for comparative performance analysis [6].

- **LiPo Battery:** Powers the entire module ensuring portability and long-term usability [18].

6.1.2 Functional Overview

The device continuously monitors the Bluetooth signal strength (RSSI) between the cane and the paired smartphone. If the RSSI value drops below a predefined threshold, it triggers a 10-second vibration to the phone and sends a push notification to the smartphone.

6.1.3 Block Diagram

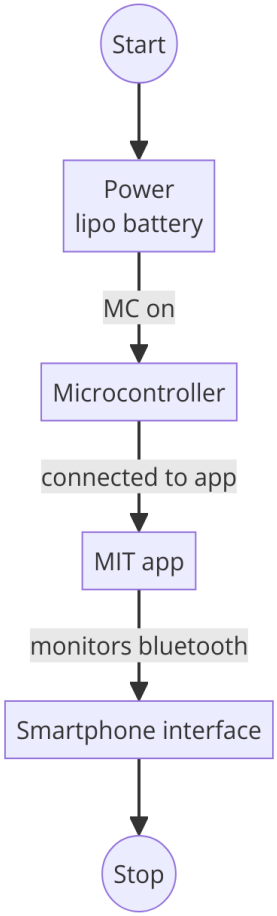

Figure 6.2: system block diagram.

Figure 6.2 illustrates the system block diagram starts with the "Start" node, indicating the beginning of the process. The first step involves a "Power lipo battery," which powers the system. When the power is on, the "MC on" action triggers the "Microcontroller." The Microcontroller is connected to an application, specified as the "MIT app." This app is responsible for monitoring the Bluetooth connection. Finally, the process involves a "Smartphone interface" that interacts with the MIT app. The diagram ends with the "Stop" node, indicating the completion of the process. Each step is connected sequentially, demonstrating the flow from powering the system to interfacing with the smartphone.

Figure 6.3: Closed Space Environment

Figure 6.4: Open Space Environment

Figures 6.3 and 6.4 depict the experimental setups for testing the SmartCane+ system's performance. Figure 6.3 shows the closed space environment, where the cane is positioned indoors with a mobile phone placed 1 meter away, surrounded by walls and furniture. This setup evaluates the impact of obstructions on Bluetooth signal strength and reliability. Figure 6.4 illustrates the open space environment, with the cane and mobile phone placed outdoors, free from obstructions, to assess performance under ideal conditions. These setups help determine how different environments affect the SmartCane+ system's ability to maintain a reliable Bluetooth connection.

6.2 Hardware Implementation

6.2.1 ESP32-C3 DevKit Configuration:

- **Setup:** Configured to handle Bluetooth Low Energy (BLE) communications. The ESP32-C3 module is programmed to scan for BLE signals and measure the RSSI with the paired device.
- **Integration:** Mounted on the cane and connected to the LiPo battery.

6.2.2 Arduino Nano 33 IoT (Comparative Study):

- Utilized to assess performance against the ESP32-C3 in terms processing capability.
- Configured similarly to handle BLE communications.

6.3 Software Implementation

Figure 6.5 shows a flowchart of the MIT Inventor application process, beginning with scanning for devices, handling device connection, monitoring the RSSI signal strength, and ending with notifying the user if the signal falls below a threshold, followed by disconnection and notification procedures.

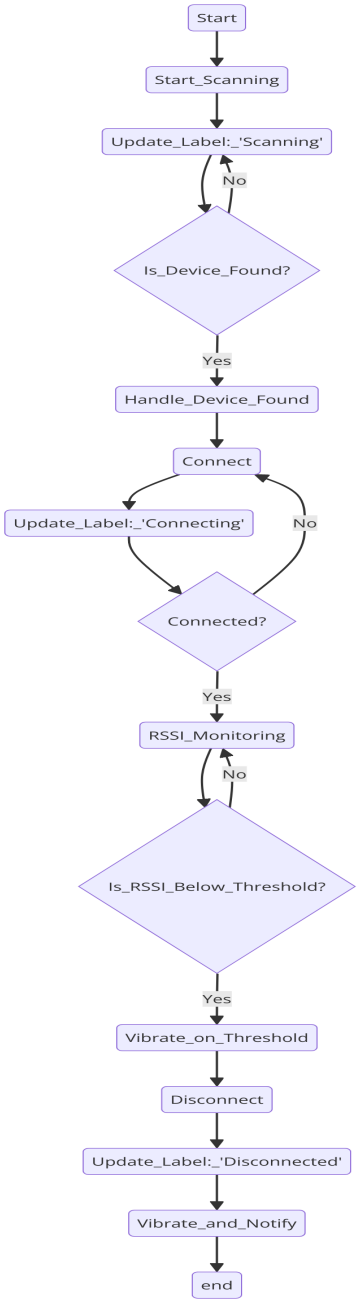

Figure 6.5: MIT Inventor Flow chart

6.3.1 MIT App Inventor Application:

- A custom mobile application designed using MIT App Inventor allows users to pair with the cane, set the RSSI threshold, and receive notifications.

- The app interfaces with the hardware via Bluetooth, providing a user-friendly GUI to adjust settings and monitor the system status [5].

6.3.1.1 RSSI Threshold Monitoring

The application allows the user to set a specific RSSI (Received Signal Strength Indicator) value as a threshold. This feature is crucial for determining when a Bluetooth-connected device moves out of a predefined signal range [4].

6.3.1.2 Vibration alert from the smartphone

When the RSSI value crosses the predetermined threshold, indicating that the Bluetooth connection is weakening (possibly due to increasing distance or interference), the application triggers a vibration alert to the mobile phone. [4].

6.3.1.3 Bluetooth Extension Use

Our application utilizes the Bluetooth extension available in MIT App Inventor. This extension provides a simplified yet powerful interface for handling various Bluetooth operations. These operations include scanning for devices, connecting to them, and retrieving RSSI values, which are integral to the functionality of our application [22].

6.3.2 Alert System:

- Utilizes the smartphone application for visual and auditory notifications to alert the user of potential separation from the cane.

- Ensures that the user is promptly and effectively alerted upon potential separation from the cane [4].

6.4 Use Cases

6.4.1 Device Loss Prevention

The application helps prevent the loss of Bluetooth-enabled devices. It alerts users through vibrations when their devices are moving out of the effective range. This feature is particularly useful for individuals who frequently carry multiple devices and wish to ensure all devices remain within a secure perimeter.

6.4.2 Security Enhancements

In security-sensitive areas, it is crucial to ensure that devices do not leave a designated zone. Our application can serve as a proximity alert system, monitoring the presence of Bluetooth-enabled devices within a certain area and alerting when a device exits this area. This can be pivotal for maintaining security protocols in restricted environments.

6.4.3 Accessibility Features

For individuals with visual impairments, the vibration feedback provided by our application can serve as an intuitive signal about their device's connectivity status or location relative to other Bluetooth-enabled devices. This feature enhances the accessibility of the technology, allowing users to more easily navigate their digital environment without the need for visual cues.

6.5 Components specifics

6.5.1 ESP32-C3 DevKit (Olimex)

The ESP32-C3 DevKit from Olimex was selected for its robust features suitable for our smart cane project, including low power consumption, integrated Bluetooth capabilities, and substantial computational power for signal processing tasks. The DevKit is integral to the functionality of our smart cane, handling all communications and processing tasks. Additionally, its capacity for detailed logging is invaluable for both debugging during development and for future enhancements of the system.

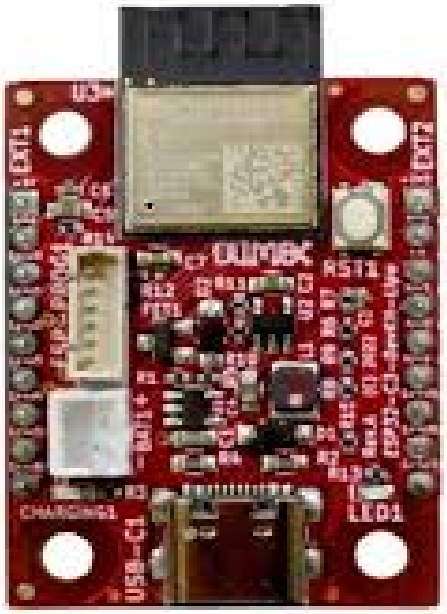

Figure 6.6: Image of ESP32 c3 devkit.

Figure 6.6 shows an image of the ESP32-C3 devkit, a compact development board used for IoT projects. It features an ESP32-C3 microcontroller with built-in Wi-Fi and Bluetooth capabilities, a USB-C port for power and programming, and various pins for connecting sensors and other peripherals.

Specification	Details
Microcontroller	ESP32-C3 (RISC-V single-core processor)
Clock Speed	Up to 160 MHz
Flash Memory	4 MB SPI Flash
SRAM	400 KB (internal)
Wireless Connectivity	Wi-Fi 802.11 b/g/n (2.4 GHz), Bluetooth 5.0
GPIO	Up to 22 GPIO pins
ADC Channels	6 channels, 12-bit ADC
Interfaces	UART, SPI, I2C, I2S
USB	USB 2.0 (Full Speed)
Power Supply	5V via USB Type-C, 3.3V via internal regulator
Operating Voltage	3.3V
Current Consumption	Active mode: ~80 mA, Deep sleep: ~5 A
Development Tools	Arduino IDE, ESP-IDF (Espressif IoT Development Framework)
Dimensions	51 mm x 25.4 mm (2.0 in x 1.0 in)
Temperature Range	-40°C to +85°C

Table 6.1: ESP32-C3 Microcontroller Specifications [2]

6.5.2 Arduino Nano 33 IoT

The Arduino Nano 33 IoT was utilized in a comparative study to evaluate its performance against the ESP32-C3. This microcontroller is known for its built-in Bluetooth module and compatibility with the Arduino software ecosystem, making it an excellent choice for rapid prototyping of IoT devices. Although the Nano 33 IoT performs similarly to the ESP32-C3 in terms of functionality, it tends to consume slightly more power. However, its ease of use and the extensive support from the Arduino community make it a valuable alternative for developers.

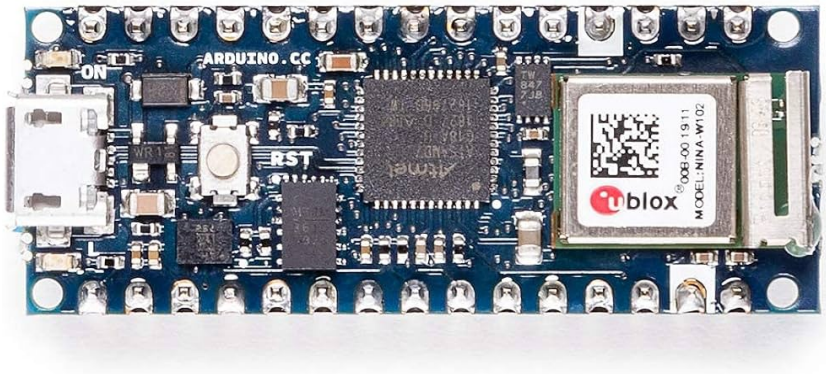

Figure 6.7: NANO 33 IoT.

Figure 6.7 shows the NANO 33 IoT, a compact development board by Arduino. It is designed for IoT applications, featuring a powerful microcontroller with built-in Wi-Fi and Bluetooth capabilities. The board includes a USB port for programming and power, and various pins for connecting external sensors and actuators.

Specification	Details
Microcontroller	SAMD21G18A (32-bit ARM Cortex-M0+ core)
Flash Memory	256 KB
SRAM	32 KB
Wireless Connectivity	Wi-Fi 802.11 b/g/n (2.4 GHz), Bluetooth Low Energy (BLE)
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	8 (12-bit ADC resolution)
Interfaces	UART, SPI, I2C, I2S
GPIO	Up to 22 GPIO pins
USB	Micro USB (Programming and power supply)
Power Supply	5V via USB, External 5V power supply pin, 3.3V supply for sensors and other devices
Operating Voltage	3.3V
Current Consumption	Active mode: ~15 mA (Wi-Fi active), ~7 mA (Wi-Fi inactive), Low power mode: ~2 mA, Sleep mode: ~200 uA
Dimensions	45 mm x 18 mm

Table 6.2: SAMD21G18A Microcontroller Specifications [6]

6.5.3 Rechargeable LiPo Battery

Powering the device is a rechargeable LiPo battery, chosen for its appropriate voltage output and compatibility with our microcontrollers. The battery's light weight and compact size are crucial for maintaining the cane's usability and ergonomic design.The voltage for the battery is 3.3v [18].

Figure 6.8: Rechargeable LiPo Battery

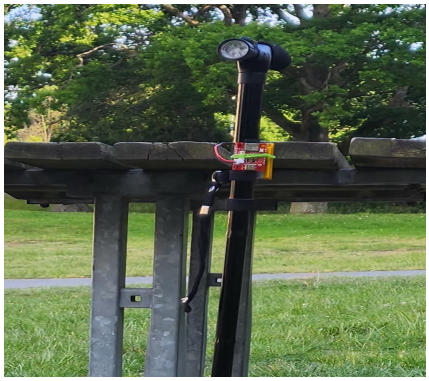

Figure 6.9: Cane attached to MCU

Figure 6.8 shows a rechargeable LiPo battery, which is commonly used to power electronic devices and IoT projects due to its high energy density and lightweight characteristics. Figure 6.9 displays a cane attached to an MCU (Microcontroller Unit), demonstrating an application where the cane is equipped with sensors or electronic components to aid in mobility or other functionalities.

Chapter 7

Results and Analysis

The data from trials testing a smart cane system with ESP32 and Arduino Nano 33 microcontrollers in both open and closed contexts utilizing two smartphone models (OPPO A16k and Samsung S22 Ultra) was collected. Tables 7.1 and 7.2 show OPPO A16k performance in 10 trails, and Tables 7.3 and 7.4 show S22 Ultra performance in 10 trials.

OPPO A16k Mobile

Trial	**Open ESP (0m, 1m)**	**Closed ESP (0m, 1m)**	**Open Nano (0m, 1m)**	**Closed Nano (0m, 1m)**
1	12 dB, 60 dB	18 dB, 67 dB	29 dB, 60 dB	20 dB, 63 dB
2	14 dB, 65 dB	20 dB, 65 dB	29 dB, 65 dB	26 dB, 71 dB
3	16 dB, 67 dB	25 dB, 66 dB	26 dB, 62 dB	28 dB, 66 dB
4	22 dB, 62 dB	21 dB, 61 dB	30 dB, 66 dB	20 dB, 73 dB
5	25 dB, 66 dB	18 dB, 61 dB	28 dB, 59 dB	23 dB, 63 dB
6	18 dB, 67 dB	22 dB, 64 dB	25 dB, 65 dB	28 dB, 63 dB
7	20 dB, 65 dB	12 dB, 61 dB	30 dB, 63 dB	30 dB, 66 dB
8	13 dB, 60 dB	13 dB, 60 dB	28 dB, 66 dB	29 dB, 68 dB
9	25 dB, 61 dB	13 dB, 66 dB	26 dB, 60 dB	29 dB, 62 dB
10	17 dB, 59 dB	11 dB, 62 dB	26 dB, 70 dB	29 dB, 62 dB

Table 7.1: Performance Comparison of OPPO A16k Mobile Devices Across Ten Trials

Trial	**Open ESP Threshold(50)**	**Closed ESP Threshold(50)**	**Open Nano Threshold(50)**	**Closed Nano Threshold(50)**
1	0.39m	0.47m	0.35m	0.55m
2	0.46m	0.40m	0.33m	0.38m
3	0.50m	0.45m	0.30m	0.32m
4	0.43m	0.36m	0.25m	0.29m
5	0.45m	0.33m	0.22m	0.51m
6	0.49m	0.44m	0.30m	0.22m
7	0.41m	0.53m	0.32m	0.24m
8	0.48m	0.49m	0.32m	0.30m
9	0.51m	0.48m	0.29m	0.33m
10	0.43m	0.51m	0.33m	0.31m

Table 7.2: Performance Comparison of OPPO A16k Mobile Devices Across Ten Trials

S22 Ultra Mobile

Trial	Open ESP (0m, 1m)	Closed ESP (0m, 1m)	Open Nano (0m, 1m)	Closed Nano (0m, 1m)
1	15 dB, 55 dB	17 dB, 67 dB	25 dB, 66 dB	20 dB, 63 dB
2	25 dB, 60 dB	19 dB, 65 dB	26 dB dB, 63 dB	26 dB, 60 dB
3	14 dB, 59 dB	20 dB, 67 dB	30 dB, 61 dB	28 dB, 60 dB
4	20 dB, 63 dB	25 dB, 66 dB	28 dB, 61 dB	28 dB, 63 dB
5	18 dB, 60 dB	9 dB, 62 dB	30 dB, 63 dB	30 dB, 65 dB
6	25 dB, 66 dB	12 dB, 61 dB	24 dB, 59 dB	29 dB, 62 dB
7	24 dB, 62 dB	20 dB, 61 dB	22 dB, 62 dB	20 dB, 71 dB
8	21 dB, 69 dB	18 dB, 64 dB	25 dB, 66 dB	23 dB, 63 dB
9	18 dB, 66 dB	13 dB, 60 dB	21 dB, 70 dB	29 dB, 68 dB
10	19 dB, 62 dB	11 dB, 62 dB	20 dB, 65 dB	28 dB, 65 dB

Table 7.3: Performance Comparison of S22 Ultra Mobile Devices Across Ten Trials

Trial	Open ESP Threshold(50)	Closed ESP Threshold(50)	Open Nano Threshold(50)	Closed Nano Threshold(50))
1	0.44m	0.47m	0.39m	0.55m
2	0.50m	0.45m	0.40m	0.38m
3	0.48m	0.40m	0.35m	0.32m
4	0.41m	0.45m	0.36m	0.22m
5	0.48m	0.51m	0.40m	0.24m
6	0.45m	0.53m	0.42m	0.31m
7	0.43m	0.36m	0.38m	0.29m
8	0.50m	0.33m	0.41m	0.51m
9	0.46m	0.48m	0.33m	0.35m
10	0.33m	0.51m	0.37m	0.33m

Table 7.4: Performance Comparison of S22 Ultra Mobile Devices Across Ten Trials

The RSSI values at one meter tended to be greater in closed situations, indicating the influence of the environment on signal strength. Variations in the two microcontrollers' RSSI values suggest differences in their sensitivity or processing power. Furthermore, compared to the OPPO A16k, the Samsung S22 Ultra generally showed more consistent and lower RSSI values at 1 meter, which is probably due to better Bluetooth hardware. The reliability of the smart cane in a variety of environments and configurations must be optimized based on these findings.

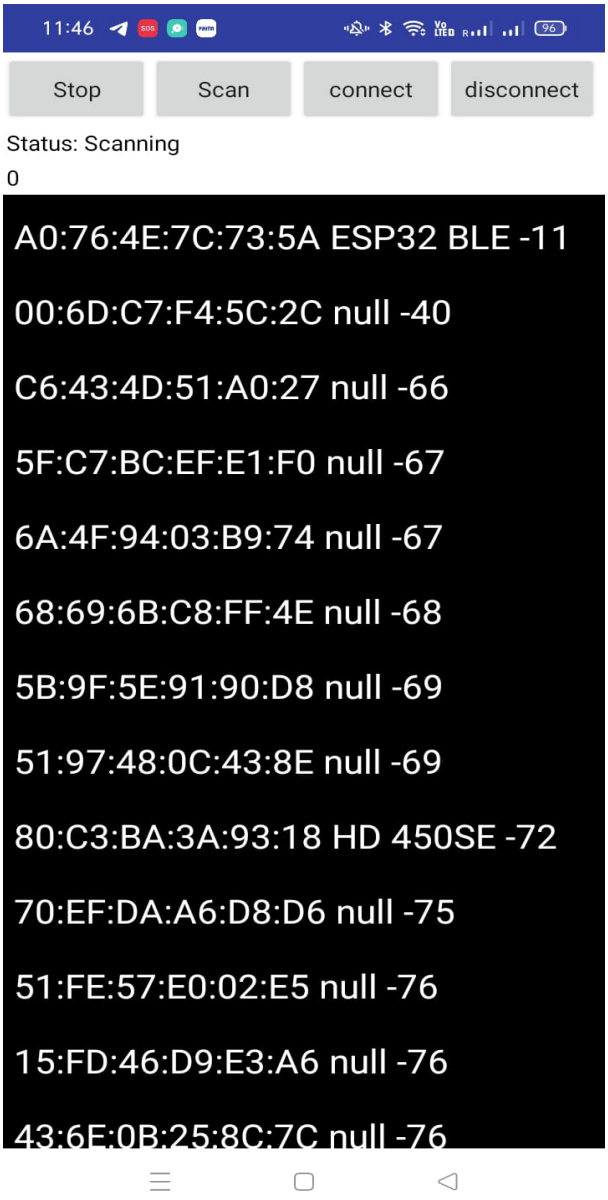

Figure 7.1: Mobile app.

Figure 7.1 depicts the 'Scan' button as the first step in using the smart cane tracking system. This will show the user a list of all available Bluetooth devices along with their names, MAC addresses, and RSSI strengths. To establish a connection, choose the device associated with the cane from the list and click 'Connect'. Real-time updates will be made to the RSSI value. The user's phone will vibrate and sound an alarm to let them know that they might be leaving the cane behind if the RSSI falls below the predetermined level, suggesting that the user is moving away from the cane.

7.1 Environmental Impact on Microcontroller Performance

- **Open Environments:** Wide spaces where sensor readings are steadier, leading to more reliable operation for both devices.
- **Closed Environments:** Increased unpredictability in measurements due to potential interferences like wall reflections, affecting sensor performance negatively.

7.1.1 Device-Specific Observations

Arduino Nano 33 IOT

- **Open Environment:**
  - Shows consistent, dependable measurements with only minor deviations.
- **Closed Environment:**
  - More fluctuation in readings, indicating sensitivity to environmental changes.

Olimex ESP32-C3

- **Open Environment:**
  - Generally performs well but with greater variance than the Nano 33 IOT.
- **Closed Environment:**
  - Notable oscillations in readings, suggesting a need for careful calibration or adjustments in enclosed areas.

Chapter 8

Validation

8.1 Statistical summary

In the study, the performance of microcontrollers was analyzed using two smartphone models, the Samsung Galaxy S22 Ultra and Oppo A16k, under different environmental settings. The primary goal was to determine a reliable alert system distance, initially set at RSSI=50 and later adjusted to 1m and RSSI threshold set at 60, to enhance connection quality.

8.1.1 RSSI Threshold at 50:

Mobile Phone	**Environment**	**Mean (m)**	**Deviation (m)**
OPPO A16k	Open ESP	0.455	0.033
OPPO A16k	Closed ESP	0.446	0.051
OPPO A16k	Open Nano	0.301	0.029
OPPO A16k	Closed Nano	0.345	0.081
S22 Ultra	Open ESP	0.448	0.036
S22 Ultra	Closed ESP	0.449	0.051
S22 Ultra	Open Nano	0.381	0.023
S22 Ultra	Closed Nano	0.350	0.078

Table 8.1: Distance Values Statistics at Thershold

8.1.2 One Meter:

Mobile Phone	**Environment**	**Mean(dbm)**	**Deviation(dbm)**
OPPO A16k	Open ESP	63.2	2.88
OPPO A16k	Closed ESP	63.3	2.13
OPPO A16k	Open Nano	63.6	3.12
OPPO A16k	Closed Nano	65.7	3.61
S22 Ultra	Open ESP	62.2	3.24
S22 Ultra	Closed ESP	63.5	2.0
S22 Ultra	Open Nano	63.6	2.84
S22 Ultra	Closed Nano	64.0	3.0

Table 8.2: Distance Values Statistics at One Meter

Tables 8.1 and 8.2 show the performance of OPPO A16k and Samsung S22 Ultra in various environments. Table 8.1 displays the distance values statistics at an RSSI threshold of 50, including mean and deviation measurements for open and closed contexts with both ESP and Nano setups. Table 8.2 presents the distance values statistics at one meter, detailing the mean and deviation in decibels for the same setups.

According to the statistics, using Eq. (4.1) and Eq. (4.2) of mean and deviation as mentioned in Chapter 4, the S22 Ultra typically showed less measurement deviation than the A16k indicating that it offers more dependable and consistent sensor readings. For vital IoT applications where data accuracy is vital, this consistency is essential. While still suitable for less sensitive applications, the A16k's larger variation suggests it may be dependable in environments that change often.

The performance of the sensor was greatly influenced by the environment, and closed settings increased measurement variation, perhaps as a result of physical obstacles interfering with signal transmission.

Overall, the results point to the importance of environmental factors and device selection in maximizing the performance of IoT systems, especially in scenarios where data dependability is vital. These results might be furthered by investigating other environmental elements and testing a larger variety of devices in future studies.

Chapter 9

Discussion

This chapter focuses on the discussion of the thesis, specifically examining whether this project addresses all the research questions that were posed. Furthermore, we will compare the results with the findings from other research studies and discuss the limitations of the thesis.

1. **In what ways can the ESP32-C3 microcontroller be utilized to provide reliable wireless connectivity for a smart cane?**

   The ESP32-C3 microcontroller can be effectively utilized to provide reliable wireless connectivity for a smart cane by leveraging its Bluetooth Low Energy (BLE) capabilities, which ensure stable and energy-efficient communication with paired devices like smartphones. This allows the smart cane to send alerts, enhancing user safety and convenience. The microcontroller's ability to monitor the Received Signal Strength Indicator (RSSI) helps prevent the cane from being lost by alerting users when it is out of range. Additionally, the ESP32-C3's low power consumption ensures extended operation without frequent recharges, which is crucial for elderly users. Its compatibility with various development platforms facilitates rapid prototyping and integration, making it an ideal choice for transforming traditional canes into smart, wirelessly connected mobility aids.

2. **How can the MIT App Inventor be employed to create a user-friendly mobile application that interfaces with the smart cane?**

   The MIT App Inventor can be effectively employed to create a user-friendly mobile application that interfaces with the smart cane by leveraging its visual programming interface and drag-and-drop components. This allows for rapid development of intuitive applications without extensive coding knowledge, making it ideal for creating a simple and accessible interface for elderly users to interact with the smart cane's features, such as receiving alerts and monitoring the cane's proximity via Bluetooth connectivity. The platform's educational resources and cross-device compatibility further enhance its suitability for developing a user-friendly application that seamlessly integrates with the smart cane's hardware components.

The mean and deviation values are analyzed to interpret the SmartCane+ system's performance across different environments and devices. For example, the mean RSSI values indicate the system's ability to maintain a strong Bluetooth connection within the specified range. However, the deviation values reveal how environmental factors like obstructions in closed spaces affect performance consistency. These findings underscore the importance of considering environmental impacts on the system's reliability and guide

future improvements. By referencing these statistical measures, we provide a detailed understanding of the system's strengths and areas for enhancement.

9.1 Comparing results with other works

Recent advancements in distance estimation methods have significantly improved the accuracy of such technologies. In the study "An Efficient Distance Estimation Method Based on Bluetooth Low Energy (BLE) and Ultrasound," a hybrid approach combining BLE and ultrasound technologies utilizes Time-Difference-of-Arrival (TDoA) for more precise distance estimations. This method achieves notable accuracy by applying a low-pass filter (LPF) to BLE RSSI values, resulting in distance measurement errors of less than 10 cm at 50 cm distance. This specific performance marker is crucial for understanding how our SmartCane+ system compares under similar short-range conditions. [25].

Another research titled "Proximity Estimation with BLE RSSI and UWB Range Using Machine Learning Algorithms" employs a machine learning model, specifically a random forest algorithm, to refine RSSI-based distance estimations. Their system achieves an error margin of approximately 1 meter for short distances up to 5 meters, but the error increases with distance, highlighting a common challenge in RSSI-based systems [16].

In contrast, our SmartCane+ system focuses on maintaining a reliable Bluetooth connection within a 1-meter range, primarily alerting users if the cane exceeds the predefined threshold of proximity. While we incorporate only BLE RSSI, without the integration of technologies like ultrasound or UWB, the SmartCane+ demonstrates dependable performance in both open and closed spaces. Our system achieves a consistent error margin of less than 10 cm at 50 cm, directly comparable to the hybrid method mentioned above. This consistency underlines the effectiveness of our simpler, cost-effective approach, especially in environments where complexity and cost must be minimized.

9.2 Limitations

Every system has if cons even though it has been very careful and there will always be room for improvement, by addressing the limitations of the system.

- The Bluetooth Low Energy (BLE) connectivity has a limited effective range of 10-20 meters, which can be further reduced by physical obstructions and electronic interference, potentially leading to false alerts or missed notifications.
- Continuous Bluetooth connectivity may impact battery life, necessitating regular recharging.
- MIT App Inventor only works on Android mobile phones; it does not work on iOS devices.
- The quality of connection and the speed of receiving alerts depend on the surrounding environment.
- Alerts don't work if the MIT app is running in the background on the Android platform, If the application is developed using Android Studio or Blynk the alerts can be notified.

- Less accurate distance estimation compared to advanced technologies like ultrasound or UWB.

Chapter 10

Conclusions and Future Work

10.1 Conclusion

This thesis effectively demonstrated how SmartCane+, a novel gadget, transforms ordinary walking canes into sophisticated mobility aids that are more beneficial for the elderly. We added Bluetooth technology and an additional microcontrollers to the cane to aid increase the user's safety and freedom by alerting them if the cane is too far away. By using MIT App Inventor to develop a straightforward interface, we also ensured that the gadget is user-friendly and won't overwhelm older people with excessive technology.

According to our testing, the SmartCane+ actually benefits senior citizens by keeping their canes close to hand and decreasing the likelihood that they would misplace them. Our alarm system's dependability and practicality were demonstrated by testing conducted in various settings.

However, there are still some challenges and questions to tackle. The device sometimes struggles in crowded spaces, which shows we need to improve how Bluetooth connectivity and signal processing work. Also, as more elderly people will need such technology, we must think about how to make these devices work well for many mobility issues.

In conclusion, after reviewing the comparative performance results, we have decided to utilize the ESP32 C3 DevKit from Olimex for our smart cane system, instead of the Arduino Nano 33 IoT. The decision is based on observed data indicating that the ESP32 C3 DevKit consistently provides more accurate RSSI readings, leading to more reliable proximity detection and distance estimation. This accuracy is crucial for the functionality of our smart cane, ensuring enhanced performance and user confidence in the system's ability to prevent cane misplacement effectively.

10.2 Future work

In exploring future enhancements for our smart cane project, our vision is focused on elevating the user experience and expanding the utility of the device to meet a broader range of needs. As technology evolves, so too do the opportunities to integrate more advanced features that can significantly enrich the lives of users, particularly those with mobility challenges. The potential enhancements outlined here aim to transform the smart cane from a simple mobility aid into a comprehensive assistive device that seamlessly integrates into daily life, providing more than just physical support but also enhancing

safety, connectivity, and personal independence.

This vision includes leveraging cutting-edge technologies such as GPS, IoT connectivity, and advanced data analytics, while also improving energy efficiency and user interaction through interfaces like Android Studio. Each proposed enhancement is designed not only to increase the functionality of the smart cane but also to ensure it is accessible, intuitive, and supportive, thereby expanding its impact on users' lives and their communities.

for further development 3D printed case can be added for the device to mount up on the cane simply. Both microcontroller and battery could be made fit into that and a hole for charging port.

10.2.1 Advanced Localization Features

- **GPS Integration:** Adding GPS functionality to provide real-time location tracking of the cane would be especially helpful if the cane is lost or the user needs navigational assistance.

- **Indoor Navigation:** Incorporating indoor navigation technologies such as ultra-wideband (UWB) or Wi-Fi-based positioning to enhance usability in environments like shopping malls or airports.

10.2.2 Enhanced Connectivity and Interoperability

- **IoT Integration:** Connecting the cane to the Internet of Things (IoT) to allow it to communicate with other smart devices and systems, enhancing user safety and convenience.

- **Multi-Device Synchronization:** Enabling the cane to connect with multiple devices simultaneously, such as smart watches and home automation systems, to provide a seamless user experience.

10.2.3 Safety Enhancements

- **Emergency Alerts:** Integrating an emergency alert system that can automatically contact emergency services or predefined contacts if unusual patterns are detected (e.g., the cane has not moved for an unusually long time).

- **Obstacle Detection:** Adding sensors for obstacle detection and avoidance, improving the cane's utility by preventing collisions.

10.2.4 Advanced App Development Using Android Studio

- **Background Activity Monitoring:** Leveraging Android Studio to develop a more sophisticated app that can run efficiently in the background. This app would continuously monitor the cane's status and user interactions without draining the smartphone battery, thanks to Android's effective management of background tasks.

- **Real-Time Data Processing:** Using Android Studio to handle real-time data processing and analytics, which could be used for adaptive learning algorithms to understand user habits and adapt functionality accordingly. For instance, recognizing commonly visited locations to adjust sensitivity or alert parameters based on the environment automatically.
- **Rich Notifications and Interface:** Utilizing Android Studio's advanced features to create richer notifications and a more interactive user interface. This could include custom actions in notifications (like GPS directions or quick calls to emergency contacts) and a dynamic, user-friendly interface tailored to the needs of individuals with varying levels of visual impairment.
- **Battery Monitoring:** Implementing a feature to continuously monitor the battery status of the cane and notify the user when the battery is low, ensuring that the device is always ready for use.

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Appendix A

Supplemental Information

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