INDOOR POSITIONING SYSTEM

BY

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ABSTRACT

This project aims to develop an indoor infrared-based positioning system utilizing a low-cost infrared transmitter and infrared receiver. Current IPS solutions suffer from imperfections and vulnerabilities, impacting their effectiveness. Issues such as inaccurate room-level positioning, radio frequency interference, and high development costs can lead to applications relying on IPS techniques providing inaccurate information to users. The primary objective of this project is to create an affordable infrared IPS capable of providing room-level accuracy and overcoming interference issues prevalent in radio-based systems. The novelty of this project lies in the use of infrared technology as the transmitted signal, emphasizing its line-of-sight characteristic, which is often considered a drawback by other systems. Additionally, the low power consumption of infrared supports the scalability and sustainability of this proposed solution, as it does not require frequent changes. The contribution of this research lies in its potential to revolutionize indoor positioning by minimizing infrastructure dependencies, mitigating interference, and offering a globally implementable solution. In terms of impact and significance, the proposed infrared IPS is positioned as a transformative solution, akin to the ubiquity of GPS. By harnessing infrared light and avoiding reliance on radio waves, the system addresses interference issues and reduces development costs, making it accessible for diverse applications.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

SHORTFORM	**Full Name Of SHORTFORM**
GPS	Global Positioning Sytem
IPS	Indoor Positioning Sytem
Wi-Fi	Wireless Fidelity
UWB	Ultra-Wideband
BLE	Bluetooth Low Energy
RFID	Radio Frequency Identification
IR	Infrared
RF	Radio Frequency
LED	Light Emitting Diode
ID	Identification
AOA	Angle of Arrival
LOS	Line of Sight
EKF	Extended Kalman Filter
IDE	Integrated Development Environment
WLAN	Wireless Local Area Network
VLC	Visible Light
QADA	Quadrant Photodiode Angular Diversity Aperture
AGV	Automated Guided Vehicle
ESL	Electron-Stimulated Luminescence
ERD	Entity-Relationship Diagram
VsCode	Visual Studio Code

CHAPTER 1

INTRODUCTION

In this chapter, we present the background of the Indoor Positioning System (IPS) background and introduce the concept of Infrared-based IPS. We also highlight the challenges faced by various existing indoor positioning methods, explain the motivation behind our research in developing Infrared IPS technology, and outline of the thesis002E

1.1 Introduction

Over the last two decades, the Global Positioning System (GPS) has ascended to prominence as the preeminent positioning mechanism, marked by integration with diverse technologies, noteworthy advancements in accuracy, and extensive adoption across industries and daily life. However, in today's increasingly interconnected world, where technology seamlessly integrates with human's daily lives, the exigency for reliable and accurate positioning systems extends beyond outdoor environments. While the GPS has revolutionized outdoor navigation by providing accurate positioning information using satellite signals, its efficacy encounters constraints when applied within indoor environments. The signals from GPS satellites often encounter difficulties in penetrating through roofs, walls, and other structures, resulting in reduced accuracy or an outright signal loss within enclosed spaces. Recognizing this limitation, the concept of Indoor Positioning Systems (IPS) emerged to uniquely address the challenges of navigating intricate indoor environments.

In contrast to traditional outdoor positioning methods that rely on satellite signals, IPS revolutionize the way of locating objects within indoor environments by coordinating a complex web of numerous signal sources. The contemporary landscape of IPS is characterized an extensive range of approaches, each contributing to the precise indoor positioning. Some standout examples include Wi-Fi technologies [1], [2], which make clever use of existing wireless networks to determine positions, and Ultra-Wideband (UWB) technologies [3], known for their exceptional accuracy achieved through time-of-flight measurements. Additionally, the indoor positioning approaches also encompasses Bluetooth Low Energy (BLE) beacons [4]–[6], Radio Frequency Identification (RFID) tags, and Visual Light Communication (VLC) systems, all coming together to provide incredibly accurate methods for indoor positioning.

In article [7], IPS techniques are categorized into seven groups: Satellite-Based, Magnetic-Based, Inertial Sensor-Based, Sound-Based (Audible Sound, Ultrasonic Sound, and Acoustic Sound), Optical-Based, Radio Frequency-Based (WiFi, BLE, RFID, and UWB), and Vision-Based (Infrared, and Visible Light). Also, as depicted in [8], Figure 1.1 shows the examination of research papers related to the most renowned IPS technologies of recent years from 2011 to 2020, offering insights into the prevalence of WiFi, UWB, and Bluetooth technologies.

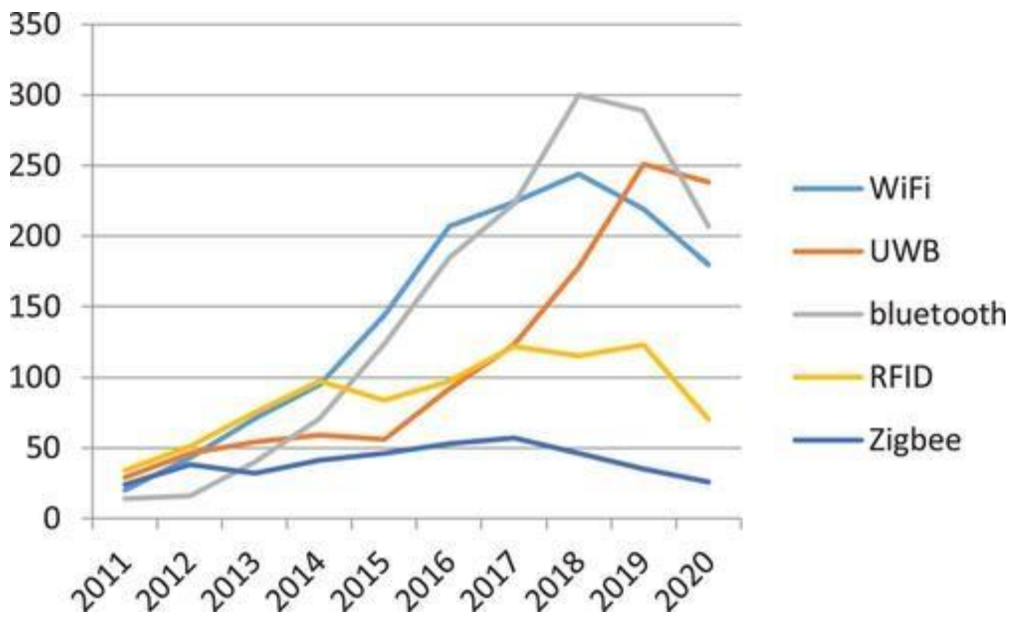

Figure 1.1 The trends of main techniques in indoor positioning [8]

Infrared-based (IR) indoor positioning remains highly competitive in comparison to other indoor positioning systems due to its near foolproof method for ensuring room-level accuracy. Unlike radio waves, infrared relies on light, which possesses a line-of-sight (LOS) characteristic and cannot penetrate through walls. This characteristic eliminates concerns about false positive results, a common issue encountered with radio wave indoor positioning systems, as radio waves can transmit through walls to the readers. Therefore, the use of infrared provides a reliable solution, ensuring precise accuracy without the complications associated with signal interference or unintended readings caused by wall penetration.

1.2 Problem Statement and Motivation

The presence of IPS indeed offers significant advantages for indoor positioning and asset tracking. However, currently deployed IPS solutions still have imperfections and vulnerabilities that hinder their effective functionality. Consequently, applications relying on IPS techniques may not work perfectly and inadvertently deliver inaccurate information to users. These problems can be outlined as follows:

1.2.1 Inaccurate Positioning on Room Level

The ability to pinpoint the relative position of an object within a dynamic environment, such as indoor spaces, presents a significant challenge, particularly in the context of radio-based indoor positioning systems. For instance, while Wi-Fi-based IPS offer a practical means of determining the location of objects or devices, they often fall short when it comes to accurately identifying which room the object is situated within. This limitation arises from the inherent characteristics of Wi-Fi signals, which can penetrate walls and obstacles, leading to signal bleed-through and ambiguity in determining precise room-level locations. While Wi-Fi signals can provide location information, they are primarily designed for data communication and not specifically for precise positioning. Because of this, identifying the position of the object accurately on room level requires another technology that can achieve higher accuracy than Wi-Fi IPS.

1.2.2 Radio Frequency Interference Issues

Radio Frequency (RF) interference is the common issues that faced by wireless IPS today. What is RF interference? It arises when unwanted electromagnetic signals within the same frequency band disrupt or degrade wireless signals and communication. In modern indoor environments, a plethora of wireless technologies coexist, including Wi-Fi networks, Bluetooth devices, and other communication systems. These technologies often share the same radio frequency spectrum, leading to potential conflicts and interference. For instance, in the case of Wi-Fi-based IPS, interference can occur due to neighboring Wi-Fi networks or non-related devices operating in the same frequency range. Similarly, Bluetooth Low Energy (BLE) IPS can experience interference from nearby BLE devices or other signals within its designated frequency band. Even UWB IPS, known for its precision, can be susceptible to interference from other RF sources in its frequency range. This interference can lead to signal fluctuations and collisions, resulting in unreliable positioning data. This interference-related problem is particularly pronounced in densely populated areas or complex indoor spaces like shopping malls or industrial facilities, where numerous wireless devices are in operation simultaneously. Thus, ensuring interference-free operation is vital for maintaining the accuracy and effectiveness of an IPS.

1.2.3 High Development Cost

In the contemporary landscape, prevalent indoor positioning systems like Wi-Fi-based, Bluetooth-based, and RFID systems require considerable development costs for the establishment of dedicated infrastructures such as beacons or tags. These infrastructures play a pivotal role in receiving signals and determining the precise positions of objects within a given space. However, the financial investment associated with acquiring such costly infrastructure, coupled with the need for additional setup, deters many organizations from embracing these technologies. Consequently, these existing indoor positioning systems face limitations in achieving global utilization, as not all enterprises are willing to bear the substantial financial burden involved in their implementation. The quest for a more accessible solution prompts the exploration of alternative technologies that can provide accurate indoor positioning without the prohibitive cost implications.

1.3 Research Objectives

The project aims to develop an ultra-low-cost infrared indoor positioning system for practical implementation. Its primary goal is to overcome the limitations of widely-used Wi-Fi indoor positioning, often falling short in providing room-level accuracy. Additionally, the project seeks to leverage invisible infrared signals to determine an object's location within a building, utilizing both an affordable infrared transmitter and receiver, which proves more economical than alternative indoor positioning technologies. This approach directly addresses the high development costs associated with other indoor positioning techniques, making implementation more accessible. Furthermore, the project aims to address the common issue of radio frequency interference encountered in indoor positioning systems. The proposed solution leverages infrared technology to effectively mitigate concerns related to interference.

1.4 Project Scope and Direction

The scope of the project involves developing an infrared indoor positioning approach that able to identify the location of the object using an infrared transmitter and a receiver. However, infrared indoor positioning is rarely implemented in real life as compare to the other indoor positioning approaches. Thereby, a thorough investigation, analysis, and practical trials are carried out to ensure the infrared IPS is worth implementing. The following outlines the project's key focus areas:

1. Conduct a comprehensive review to identify relevant research on Infrared Indoor Positioning System.
2. Develop a system model for the proposed Infrared IPS.
3. Build and deploy the infrared indoor positioning infrastructure, including the necessary hardware, software, and communication protocols.
4. Conduct experiments to validate the performance of the developed Infrared IPS in real-world indoor environments.
5. Evaluate the effectiveness of the proposed Infrared IPS in indoor positioning and compare with the other IPS.
6. Document the system design and project results and develop recommendations for future research and development.

1.5 Project Contribution, Impact, and Significance

In this rapidly evolving technological landscape, it's evident that the pace of innovation is relentless. Technological advancements continually push the boundaries, shaping how humans interact with the world. GPS has become an essential tool deeply ingrained in human's daily lives. However, the realm of IPS presents a different scenario. IPS still lacks the widespread recognition enjoyed by GPS, despite the existence of numerous solutions. Challenges like limited accuracy, high costs, and the need for additional infrastructure have hindered the global implementation of IPS technology. Therefore, the contribution behind this project is the belief in its potential to bridge the gap between indoor and outdoor positioning and even achieve widespread recognition and usability similar to GPS.

In contrast to relying on existing Wi-Fi and Bluetooth for signal transmission, our approach harnesses the power of **invisible infrared light** emitted by an infrared transmitter. This strategy significantly **reduces the dependence on extensive infrastructure** during the development of the proposed Infrared-based IPS. The process involves transmitting a specific signal carried by invisible infrared light, which is then analyzed using an infrared receiver connected to an ESP32. This analysis enables the determination of the object's location within a designated area. Notably, this method not only makes the proposed solution **cost-effective** but also **time-efficient**. Taking advantage of the prevalence of LEDs within building structures, we can conveniently install the infrared transmitter inside these structures, streamlining the overall implementation process. Additionally, our infrared IPS, not relying on radio waves, **addresses interference**, which is known as a prevalent issue encountered in existing indoor positioning approaches. Considering the benefits stated above, the proposed infrared IPS has the potential to become a solution that can be **implemented worldwide**, similar to what GPS has achieved.

1.6 Report Organization

This report is well structured to cover all the aspects of our project on indoor positioning system. Chapter 2 will undertake a comprehensive review of the existing literature in the realm of infrared indoor positioning, laying a foundation for comprehending the significance of our research within this context. Progressing to Chapter 3, the system design is comprehensively explored through various diagrams, including the system architecture diagram, entity-relationship diagram (ERD), use case diagram, and proposed system model. These diagrams provide a visual representation of the proposed indoor positioning system's components, interactions, and functionality. Additionally, Chapter 4 elaborates on the specifications of the system components, including hardware, software. Furthermore, the integration of Firebase services into the system is discussed. The chapter also outlines the interaction operations between the system components, emphasizing the intricate exchanges that enable the system's functionality, such as signal transmission, reception, decoding, database synchronization, and mobile application display. In Chapter 5, the emphasis is on system implementation, detailing the hardware and software setup involved in establishing the ultra-low-cost infrared indoor positioning system. Chapter 5 also highlights the system operation through screenshots, addresses implementation challenges encountered, and concludes with a remark on the successful establishment of the system. Moving on to Chapter 6, the focus shifts to system evaluation and discussion. This chapter begins by presenting the testing setup and results, including accuracy testing, range testing, locking time analysis, and robustness testing. The evaluation process provides insights into the system's performance, highlighting its effectiveness in achieving room-level accuracy, fast locking times, and resilience to environmental factors. Additionally, Chapter 6 discusses the challenges faced during the project and how they were addressed, demonstrating adaptability and problem-solving skills. Finally, this chapter concludes with a remark on the significance of the system's implementation and its potential for practical deployment. In Chapter 7, the report concludes with a comprehensive summary and reflection on the project.

This meticulous structure ensures thorough coverage of all critical components, providing readers with a comprehensive understanding of our research endeavors in the realm of infrared indoor positioning systems.

CHAPTER 2

LITERATURE REVIEWS

In this chapter, we will provide a summary table comparing each indoor positioning technology along with their strengths and limitations. Afterward, we will discuss previous works on Infrared-based IPS and the Automated Guided Vehicle with an infrared localization approach, which has the potential to be used in warehouse asset management.

2.1 Comparision between Indoor Positioning Technologies

The selection of indoor positioning technologies is inherently dependent on the specific requirements and characteristics of the scenario in which they are applied. No single technology can achieve a perfect fit for all indoor positioning scenarios. Each technology, whether it be WiFi, RFID, Ultrasonic, Bluetooth, UWB, Infrared, or Visible Light, comes with its own set of advantages and disadvantages. For instance, WiFi might be well-suited for environments with existing infrastructure, while Ultrasonic systems could excel in real-time applications. RFID, on the other hand, may be cost-effective but is limited by its range. The high accuracy of UWB makes it ideal for precise industrial applications, whereas Infrared technology might be more appropriate for overcoming line-of-sight challenges. In essence, the choice of technology should be driven by the specific needs, constraints, and characteristics of the indoor environment in question, emphasizing the importance of a tailored approach to achieve optimal performance in different scenarios.

According to article [7], [9], [10], we have compared current indoor positioning technologies and summarized the findings in Table 2.1.

Table 2.1 Summarization of the advantages and disdvantages of each indoor positioning technology

Technology	Advantages	Disadvantages
Wireless Local Area Network (WLAN)	• Uses existing Wi-Fi infrastructure. • Widely available in buildings • Cost-effective. • Simple to use.	• Additional access points may be needed for accuracy. • Accuracy affected by obstacles like walls and people
Radio-Frequency Identification (RFID)	• Passive RFID: Low cost, short-range. • Active RFID: Longer range. • Widespread usage in object identification.	• Active RFID can be more expensive. • Estimating location may take time. • RFID receivers report detectability, not signal strength. • Accuracy may decrease in large coverage areas
Ultrasonic	• Non-intrusive to users. • High accuracy (within several centimeters)	• Requires new infrastructure in every room. • Signal may be affected by surroundings, limited penetration through walls
Bluetooth	• Ubiquitous in smartphones and peripherals. • Low implementation cost • Easily used in indoor positioning	• Locating delay in some systems. • Power consumption can be high • Complex signal processing for good accuracy

	• Commonly used for short-range communication	
Inertial	• Uses accelerometers and gyroscopes. • Dead reckoning technique. • Particle filtering for error reduction.	• Accumulation of errors over long distances. Often used in combination with other technologies.
Ultra-wideband (UWB)	• High accuracy. • Low power requirements. • Effective in environments with pervasive IPS usage. • Minimal interference with other RF systems	• Costly equipment and installation. • Users' location known at all times. • Complex implementation requiring signal acquisition, synchronization, and tracking
Infrared (IR)	• Low-cost technology • Overcomes NLoS issues	• Limited range, requires line-of-sight • Complex sensor design for high SNR
Visible Light (VLC)	• Generally available spectrum • Less susceptible to multipath propagation	• Limited range, requires line-of-sight

Navigating the trade-offs among key features such as coverage, the number of receivers needed, accuracy, and cost poses a significant design challenge for indoor positioning systems. Achieving a balance in these aspects is crucial for the scalability of locating systems in large spaces. For instance, optimizing coverage may require deploying a higher number of receivers, which can enhance accuracy but at the cost of increased infrastructure and expenses. Conversely, cost-effective solutions may sacrifice some degree of accuracy or coverage. Striking the right equilibrium is essential, as scalability hinges on the system's ability to efficiently and accurately position users across expansive indoor environments. Designers and implementers must carefully consider these trade-offs based on the specific needs and constraints of the intended application, aiming to create a system that maximizes performance while remaining practical and cost-effective for large-scale deployment.

2.2 Previous Works on Infrared-based IPS

In this project, we are going to develop an Infrared-based IPS with a straightforward implementation using infrared transmitters and infrared receiver sensor modules. Thereby, we are going to further conduct a comprehensive exploration of existing research with analogous functionalities or structures in Infrared-based IPS for indoor positioning.

In the article [11], the authors present a study involving the use of four infrared LED lamps as transmitters and a Quadrant Photodiode Angular Diversity Aperture (QADA) as a receiver to establish a 3D infrared indoor positioning system. The identification of the transmission signal from each infrared LED is accomplished by the receiver using 1023-bit Kasami sequences, enhancing the system's capability to handle low signal-to-noise ratios and harsh multipath conditions. Following this, the points of incidence of the infrared emission on the QADA receiver are processed through the proposed algorithm to estimate the polar angle of the receiver. Subsequently, the study delves into investigating the receiver's local position through geometrical considerations. The proposed solution effectively addresses the issue of precision in indoor positioning, yielding convincing results with a general absolute error of 0.9° in polar angle estimation and 12 cm of absolute error in the receiver's local coordinates *(x, y)*. Figure 2.1 showed the system model in [11].

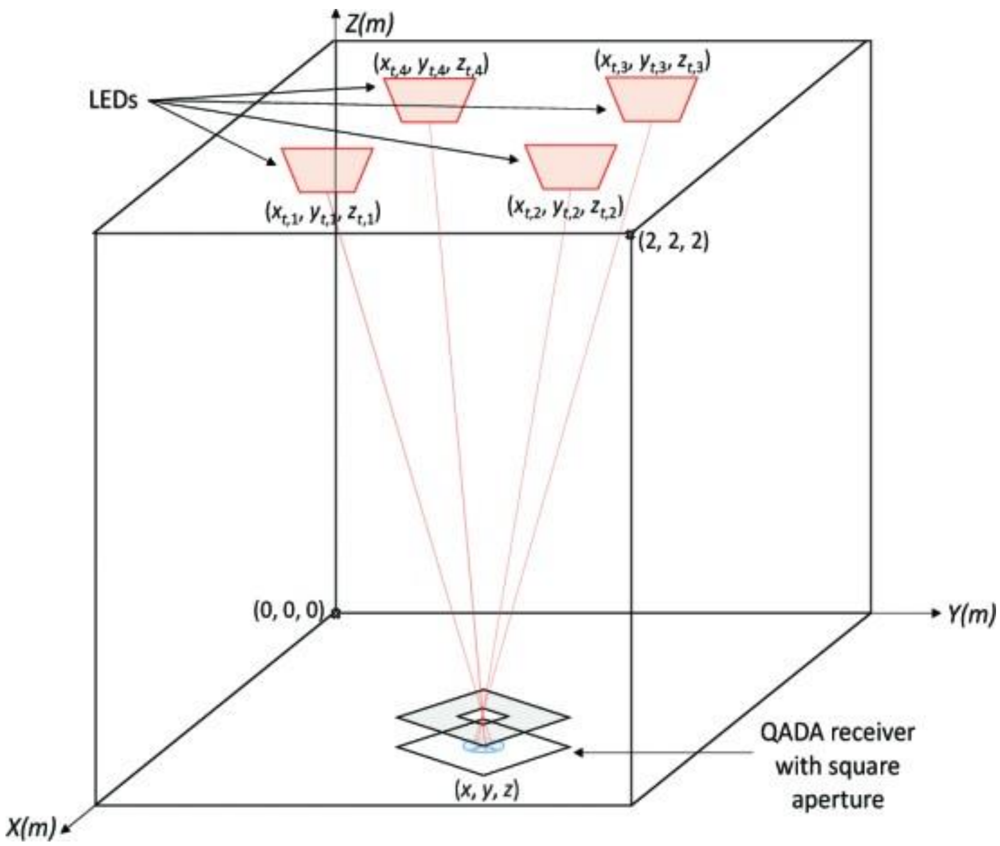

Figure 2.1 Proposed positioning system with 4 infrared LED emitters and QADA [11]

However, it is essential to note that the obtained results exhibit a strong dependence on the incidence angle, suggesting potential variations in system performance based on the receiver's location and the selected polar angle. Additionally, it is crucial to assess the system's robustness in diverse environments, considering factors such as changing lighting conditions and moving obstacles. The current study primarily focuses on simulation and experimental verification, relying on a pre-defined scenario, and lacks real-time implementation. To account for real-world factors, the study should further conduct extensive field tests in various indoor environments with different characteristics. This approach would provide a more comprehensive evaluation of the system's performance and applicability in practical scenarios.

Furthermore, in [12], the authors proposed a similar innovative optical measurement system utilizing infrared LEDs attached to customer shopping baskets for tracking people's movement, especially in retail settings. The architecture of the IR system, as depicted in Fig. 4, comprises beacons attached to objects, ceiling-mounted receivers, and a processing PC. The distinctive IR signal, combined with a coded identification number, is periodically emitted by the IR LED within the IR beacon attached to customer shopping baskets, thereby recognizing each customer's position.

Meanwhile, the IR signal received by the position-sensitive device (PSD) in the receiver generates two currents based on the IR luminance distribution. These currents, along with the decoded ID, are transmitted to the aggregation server via Zigbee. The angle of arrival (AoA) and the displacement of the center of gravity of the luminance distribution, P, are calculated using the ratio of the two currents.

With the derived AoA and P, the static position of the object is measured. In experimental evaluations, the system demonstrated static positioning capabilities in an aisle surrounded by metal shelves, with significantly lower average errors (122 mm) compared to a BLE system (648 mm). Meanwhile, dynamic positioning capabilities were assessed through experiments simulating a pedestrian walking through a store, which also show the result of the IR system is more accurate than that obtained with the BLE system.

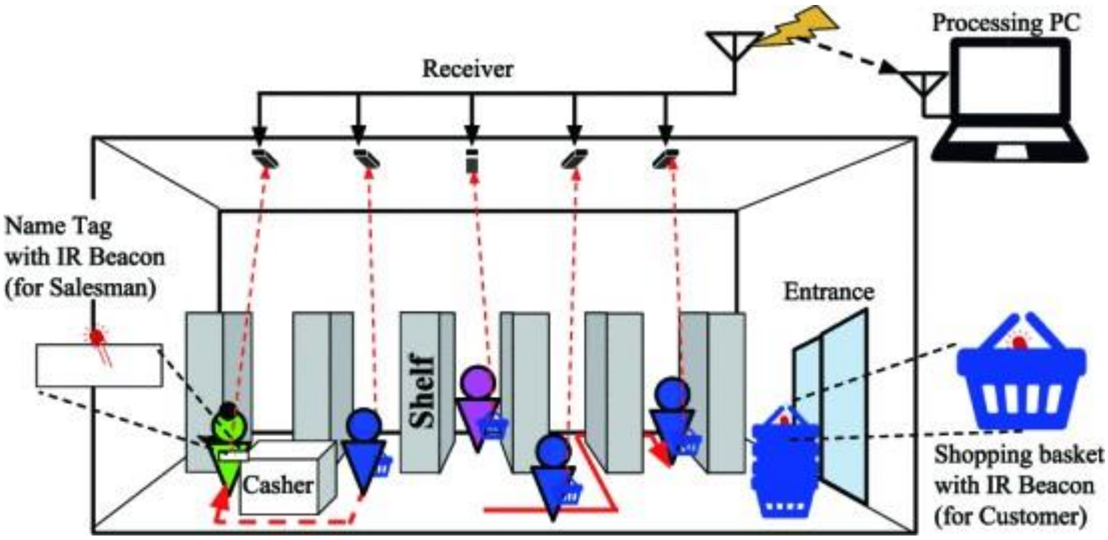

Figure 2.2 Overview of system installation in a store [12]

The proposed system offers distinct advantages, including resistance to metal interference, individual customer identification through unique IR beacon patterns, low-cost yet high accuracy positioning capabilities, compact and easily attachable beacons, and a simplified calibration process based on Angle of Arrival (AoA) technology. However, the system’s performance with multiple beacons has not been thoroughly explored in previous experiments. The scalability and accuracy of the system when multiple customers with IR beacons are present in a retail environment should be investigated to ensure its reliability.

Moreover, in article [13], the authors proposed the Indoor Receiver Localization and Positioning System (IRLPS) consists of four key components: four infrared LED beacons, a mobile receiver module, a synchronization system, and a Quadrature Angular Diversity Aperture (QADA) receiver. The system operates in two coordinate systems: global Cartesian coordinates (x, y, z), whose origin is the center of the room and local 2D coordinates (x_r, y_r) within the QADA receiver, whose the origin is the center of the QADA. As depicted in Figure 4.3, the ceiling of the room hosts four infrared light LEDs positioned at its central part, forming a square configuration with each LED placed at the four corners, creating a square with a side length of 1.2 meters. In contrast, the receiver is situated on the room's floor..

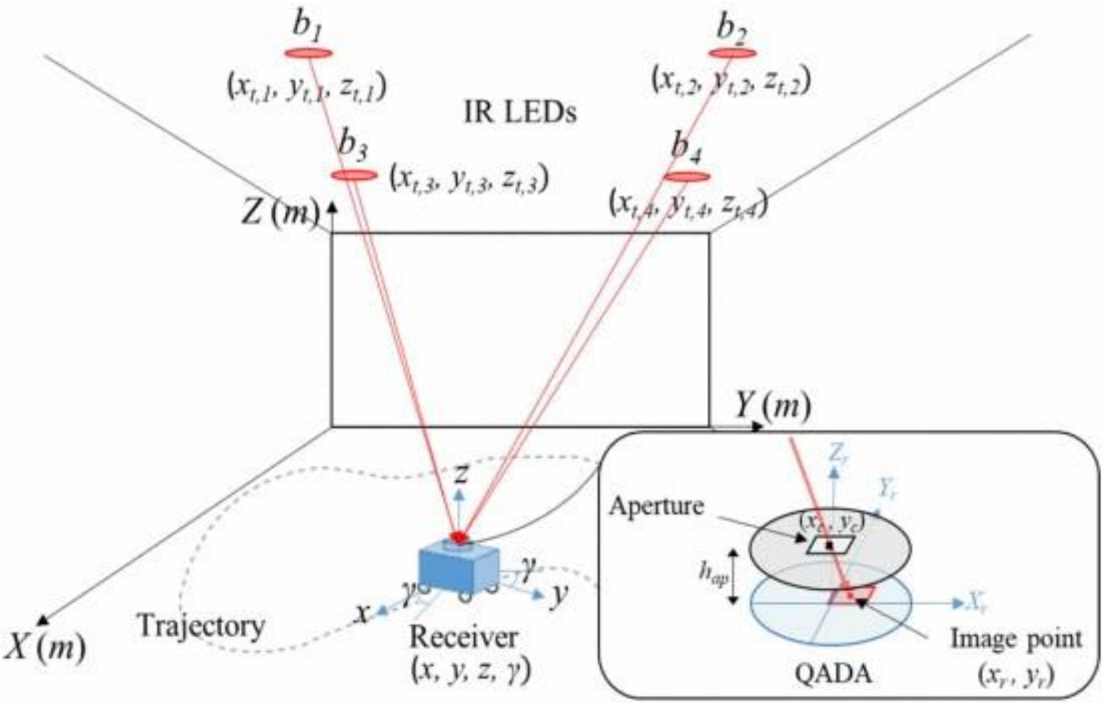

Figure 2.3 Global overview of the proposed positioning system and geometrical representation of the QADA receiver [13]

The infrared LED beacons emit LS sequences with Binary Phase Shift Keying (BPSK) modulation, and the receiver module includes a QADA photodiode, a filtering stage, a synchronization signal detector, and an acquisition system. Upon receiving the synchronization pulse, the acquisition system initiates the sampling of the incoming signal. Subsequently, the QADA photodiode, with four quadrants, measures the signals, which are then subjected to filtration and stored on a micro-SD card for subsequent processing. The signals are correlated with transmitted codes for identification. Then, the correlated signals' ratios lead to the estimation of image points (x_r, y_r) with the application of an Extended Kalman filter (EKF), and these points are geometrically related to the 3D coordinates of the LED transmitters.

The system's approach offers a comprehensive solution for precise indoor positioning using optical signals and photodiode measurements, effectively addressing the challenges of confined environments. However, in this study, the primary components, specifically the infrared LED beacons ILH-IW01-85NL-SC201-WIR200, are priced at RM70 and above per one [14]. Additionally, the circular photoreceptor QADA receiver QP50-6-18u-TO8, is valued between US$70.00 and US$115.00 [13]. The considerable expense associated with these components contrasts with our proposed solution, which places a strong emphasis on minimizing development costs.

2.3 AGV with Infrared Localization

In article [15], the authors proposed an indoor localization system for Automated Guided Vehicle (AGV) adopts a hybrid approach, combining an IR-positioning system with inertial sensor systems to create a cost-effective, scalable, and highly precise solution for large indoor environments. The IR-positioning system relies on triangulation using IR-laser beacons, distributed in both vertical and horizontal planes, allowing for precise target positioning. Upon receiving information regarding the angles obtained from the two distinct sweeps, the AGV's precise position is determined at the intersection of these two lines as depicted in Figure 2.4.

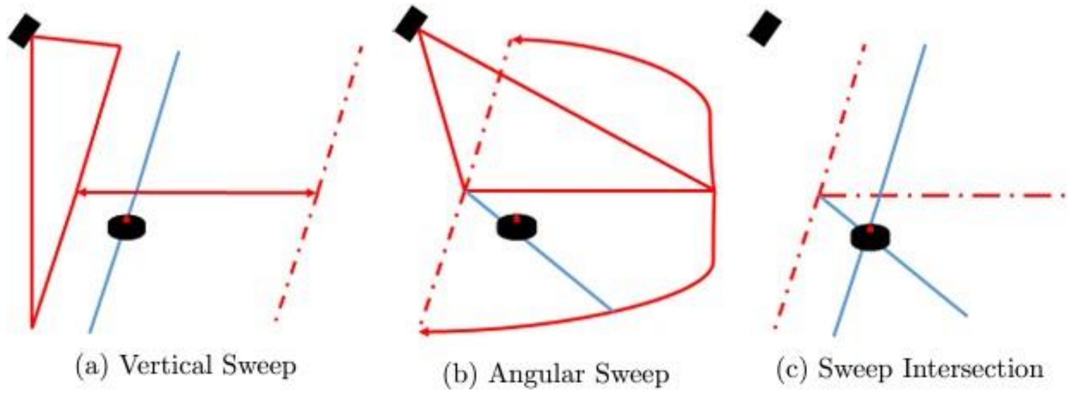

Figure 2.4 Vertical sweep, angular sweep, and sweep intersection [15]

The triangulation process necessitates trigonometric calculations utilizing the distances and angles acquired from the IR scanner. The computation involves determining the position of the receiver, which is the AGV, relative to the IR scanner position. Consequently, it is imperative to have knowledge of the angle and position of the IR scanner in this context. Subsequently, the obtained result can be transformed to align with a coordinate system, like an XY plane on the floor.

Furthermore, the authors have evaluated the robustness of the indoor localization system through the several tests, including susceptibility to external light sources such as halogen lamps, Electron-stimulated luminescences (ESLs), and LEDs, communication range, and communication speed. Results indicate vulnerability to halogen lamps within a limited range, prompting suggestions for improvements. The system also undergoes tests for communication range, indicating limitations beyond 2500mm due to laser power output and signal processing constraints. The communication speed is explored, revealing a maximum frequency of 40kHz before signal distortion occurs. Robustness tests demonstrate resilience to ESLs and LEDs.

Moreover, the system's accuracy is examined, with the IR-scanners achieving the desired precision of ±3cm. The discussion acknowledges the system's potential applicability in semi-open indoor environments, such as warehouses, considering its low cost relative to alternatives like LiDAR. Nevertheless, challenges arise due to limitations in range, update frequency, and reliability when dealing with highly mobile targets.

CHAPTER 3

SYSTEM METHODOLOGY/APPROACH

3.1 System Design Diagram

3.1.1 System Architecture Diagram

In this project, we will employ an infrared receiver sensor module to accurately interpret signals emitted by an infrared transmitter, seamlessly integrated with an ESP32 processing unit. To facilitate this integration, we will leverage the Arduino IDE to configure the ESP32, ensuring optimal functionality and compatibility. The interpreted data, crucial for precise indoor positioning, will be efficiently stored in the Firebase Realtime Database, enabling seamless data management and accessibility. Additionally, users will have access to a mobile application built using the Flutter framework, which will display their location in real-time on an indoor map, with their position represented by a distinctive red marker. The overall system architecture is shown in Figure 3.1:

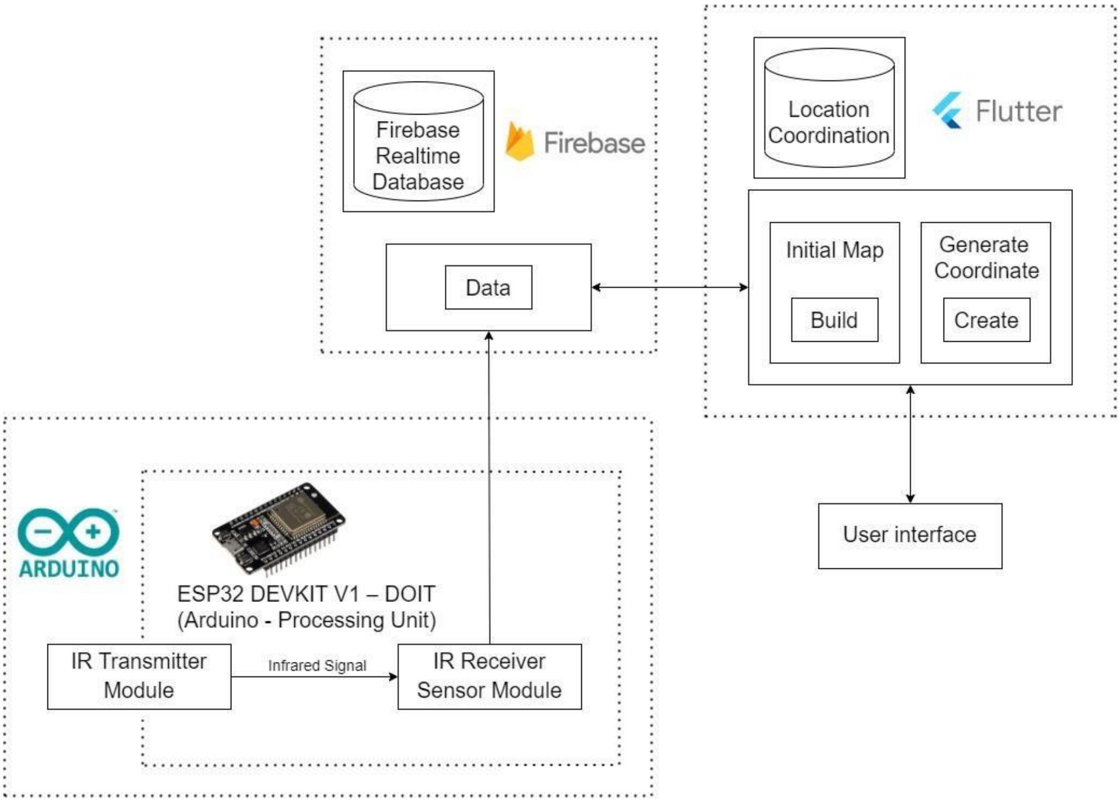

Figure 3.1 System Architecture Diagram

3.1.2 Entity-Relationship Diagram (ERD)

Figure 3.2 illustrates the Entity-Relationship Diagram (ERD) for the proposed IR indoor positioning system. In this diagram, each infrared transmitter corresponds to a unique location. Additionally, a transmitter can transmit signals to one or multiple receivers. Conversely, an infrared receiver can receive signals from one or many transmitters. Furthermore, each receiver can send data to one or multiple real-time databases. Finally, real-time databases, distinguished by different keys, can receive data from one or many infrared receivers.

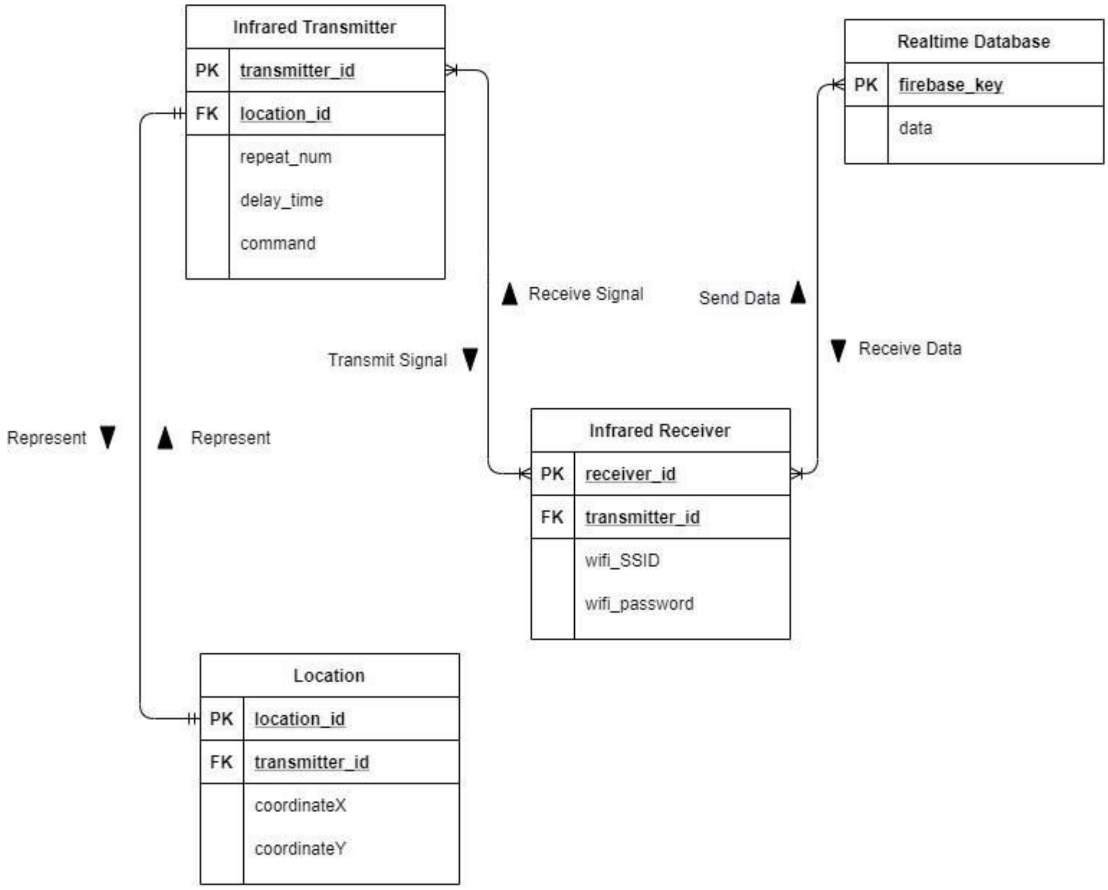

Figure 3.2 Entity-Relationship Diagram

3.1.3 Use Case Diagram

Figure 3.3 illustrates about a use case scenario for the proposed indoor positioning sysytem in this project. In this use case scenario, the end user interacts with a mobile application designed to provide indoor positioning assistance. The user's primary action involves viewing an indoor map within the application interface. To enable this functionality, the application retrieves real-time data from a Firebase Realtime Database service. Concurrently, at various locations within the indoor environment, infrared transmitters continuously transmit signals encoded with location information. Upon receiving these signals, infrared receivers located within the designated area capture and decode them. This process extends to include the transmission of decoded data, facilitating seamless communication between the receiver and the database service. Ultimately, this integrated system ensures that users can effortlessly access indoor spaces with real-time location updates.

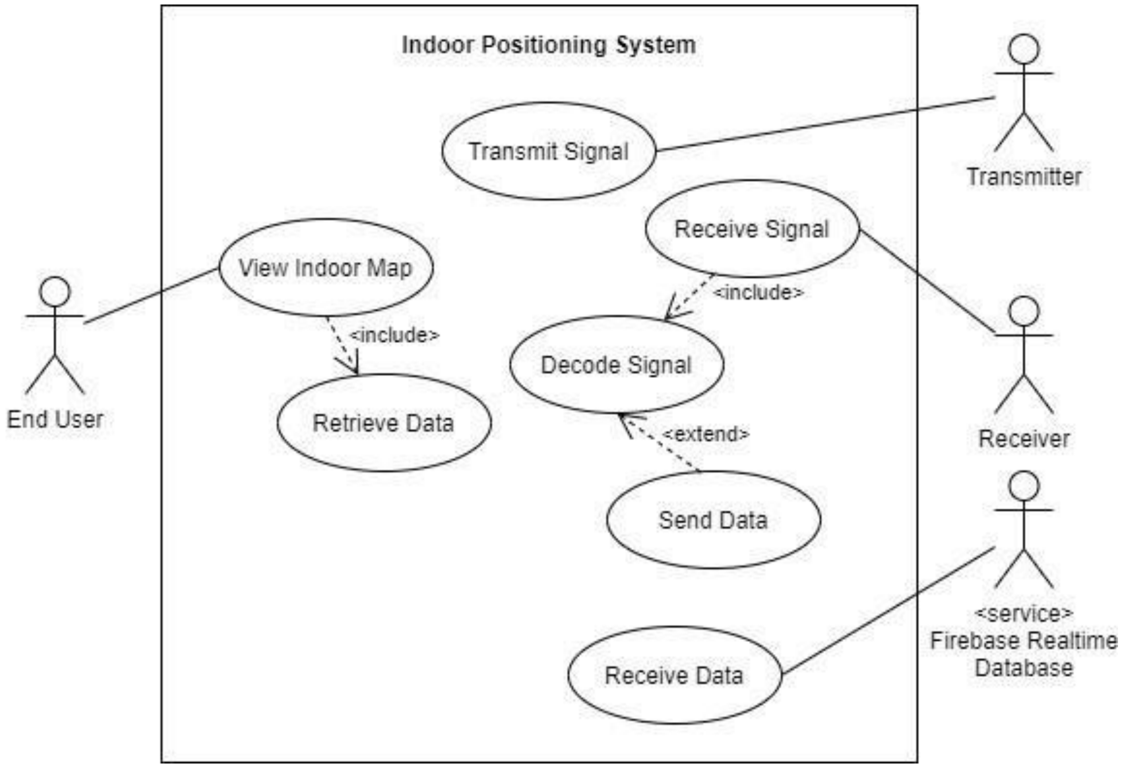

Figure 3.3 Use Case Diagram

3.1.4 Proposed System Model

Figure 3.4 depicts the proposed system model for this project, which consists of four tubes connected together to form a square shape on top. These tubes will hold the infrared transmitters at four different positions. Additionally, an AGV (Automated Guided Vehicle) equipped with the infrared receiver will move around to capture the transmitted signals. Upon successfully receiving and interpreting a complete infrared signal, the system will display the corresponding location on the indoor map within the application.

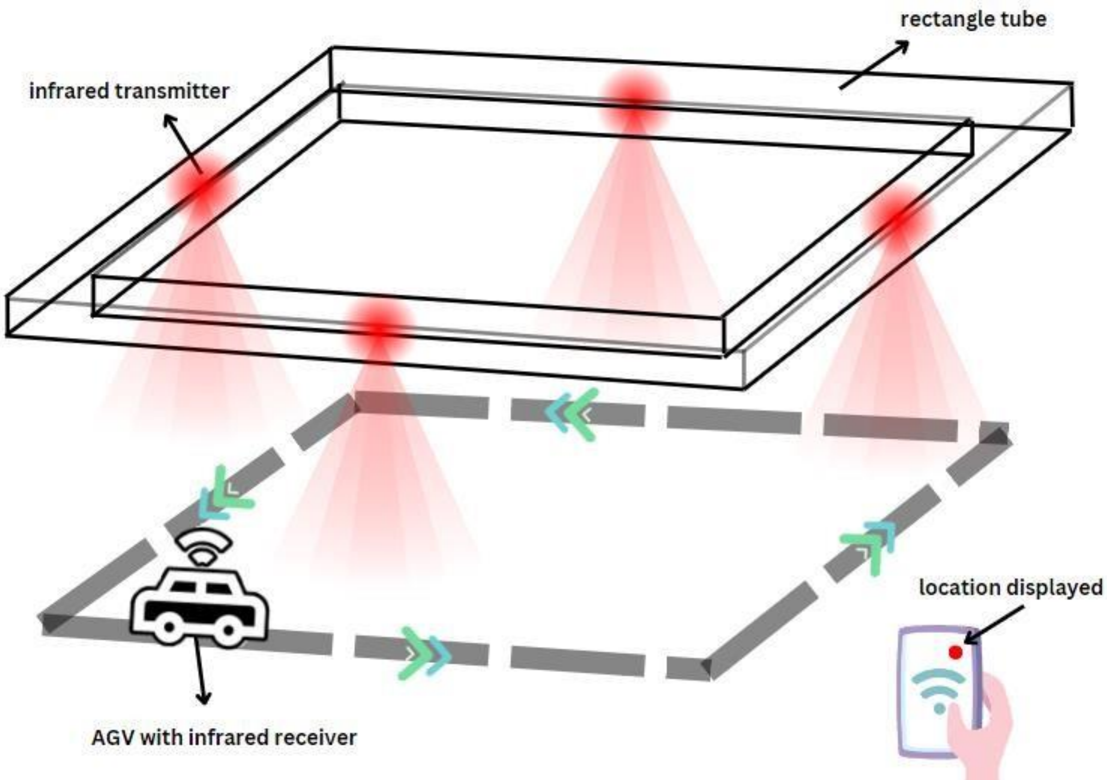

Figure 3.4 Proposed System Model

3.2 Novelties

The indoor positioning system utilizing infrared technology introduces a groundbreaking approach to location tracking by harnessing the line-of-sight characteristic inherent to infrared signals. This innovative approach addresses inherent weaknesses in conventional methods such as WiFi, Bluetooth, and UWB, which are susceptible to interference and signal attenuation. By capitalizing on infrared's direct line-of-sight transmission, the system overcomes these limitations, offering unparalleled accuracy and reliability.

One of the system's notable achievements is its ability to achieve room-level accuracy, a feat unmatched by existing technologies. As the receiver traverses predefined areas, it precisely detects and decodes signals emitted by transmitters, enabling real-time localization with pinpoint accuracy. Moreover, the versatility of this concept extends beyond single-level environments, as it can be seamlessly implemented in multi-story buildings, accommodating diverse architectural layouts and facilitating location tracking across multiple floors. This adaptability underscores the system's potential to revolutionize indoor positioning across various sectors, including retail, healthcare, and logistics, where precise location data is essential for enhancing operational efficiency and customer experience. In essence, the utilization of infrared technology in indoor positioning represents a paradigm shift in location-based services, offering unprecedented accuracy, reliability, and scalability in navigating complex indoor environments.

Moreover, concerning scalability, the ultra-low cost associated with infrared receivers and transmitters makes this proposed solution potentially widely implementable, thereby enhancing its scalability—a feat not currently achievable based on our observations. Instead of relying on existing infrastructure such as WiFi access points and Bluetooth, which are commonly considered easier ways to implement indoor positioning systems, we are exploring a new approach. This involves utilizing the infrared transmitter and infrared receiver to pinpoint an object, and make the solution become competitive with other current indoor positioning technologies in the realm of indoor positoning system.

CHAPTER 4

SYSTEM DESIGN

4.1 System Block Diagram

Figure 4.1 depicts the proposed indoor positioning system, which comprises three components: the infrared receiver, infrared transmitter, and mobile application. The infrared receiver component initiates by connecting to a specific WiFi network using the designated SSID and password. Subsequently, it proceeds to receive infrared signals emitted by the infrared transmitter component. Upon reception, it decodes the infrared signal and transmits the interpreted address data to the Firebase Realtime Database. Additionally, the block diagram emphasizes the functionality of the mobile application. Initially, the application initializes the indoor map and establishes a connection with the Firebase Realtime Database. Continuously, the mobile application retrieves the address data of the transmitter and displays the respective location accordingly.

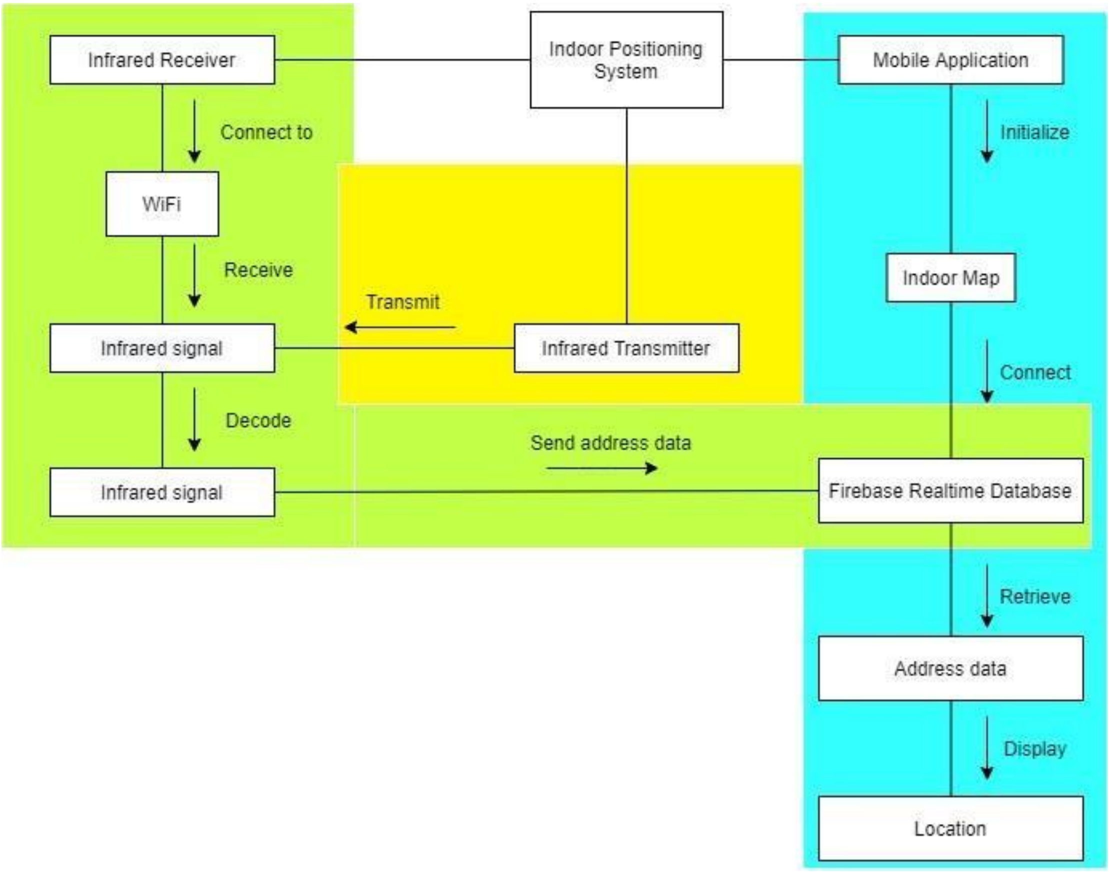

Figure 4.1 System Block Diagram

4.2 System Componenets Specifications

During this project, hardware, software, and services are required to develop the Infrared-based indoor positioning system. The necessary hardware includes an infrared transmitter, infrared receiver, ESP32 development board, and laptop. Software required for the project includes Arduino IDE, Visual Studio Code, and Flutter, followed by the service of Firebase.

4.2.1 Hardware

<u>Infrared Transmitter</u>

Infrared transmitter selected for this project is Infrared Transmitter Module. The working voltage is 5V and its wiring instructions is as below:

1. DAT - digital output interface
2. VCC - 5V DC power supply positive
3. GND - 5V DC power supply negative

The infrared transmitter in this project capable of emitting a strong infrared signal which is crucial for us to determine the location within the designated area of an object in this project.

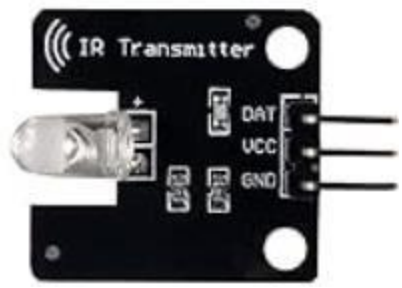

Figure 4.2 Infrared Transmitter Module

<u>Infrared Receiver</u>

Infrared receiver selected for this project is Infrared Receiver Sensor Module which can adopt 1838 remote control receiver with high sensitivity. The working voltage is 5V and its wiring instructions is as below:

1. DAT - digital output interface
2. VCC - 5V DC power supply positive
3. GND - 5V DC power supply negative

Figure 4.3 Infrared Receiver Sensor Module

ESP 32 Development Board

Table 4.1 Specifications of ESP32 Development Board

Description	**Specifications**
Type	ESP-WROOM-32 module (DOIT ESP32 DEVKIT V1)
Wireless Protocol	Wireless 802.11 b / g / n standard
Bluetooth Version	BLE 4.0
Operating Frequency	2.4 GHz to 2.5 GHz
Data Transmission rate	150 Mb/s
Output Power	20 dBm
Operating Voltage	2.7 – 3.6V
Operating Temperature	- 40 to 85 ℃
Dimension	52 mm x 28 mm x 14 mm

Laptop

Table 4.2 Laptop hardware specifications

Description	Specifications
Model	MateBook D15
Processor	AMD Ryzen 7 3700U with Radeon Vega Mobile Gfx 2.30 GHz
Operating System	Windows 10
Graphic	Intel® Iris® Xe Graphics / Intel® UHD Graphics 620
Memory	8GB
Storage	512GB SSD

4.2.2 Software

Arduino IDE

Arduino Integrated Development Environment (IDE) is an open-source platform used for writing, compiling, and uploading code to Arduino-compatible microcontrollers. It provides a user-friendly interface for developing and programming Arduino-based projects, making it accessible for both beginners and experienced developers.

Visual Studio Code

Visual Studio Code (VScode), developed by Microsoft, stands as a versatile and robust code editor that caters to the evolving needs of contemporary developers. Accessible across multiple platforms, including Windows, macOS, and Linux, it ensures a consistent and seamless editing experience irrespective of the operating system in use. Noteworthy are its intelligent code editing capabilities, encompassing features such as syntax highlighting, code completion, and snippet integration, facilitating efficient and precise coding practices. Furthermore, its integration with Git for version control enables project management and collaboration with utmost convenience. Complemented by its built-in debugging support and integrated terminal, VScode streamlines the development workflow, facilitating debugging, testing, and deployment processes.

Flutter

Flutter is an open-source UI development framework developed by Google, designed to enable developers to build natively compiled applications for mobile, web, and desktop platforms from a single codebase. Flutter leverages the Dart programming language and offers a rich set of pre-built widgets and tool that streamline the process of building expressive user interfaces. Flutter's layered architecture and flexible design make it highly customizable, empowering developers to create visually stunning and performant applications tailored to their specific needs.

4.2.3 Services

Firebase

Firebase, a comprehensive platform provided by Google, serves as a powerful toolset for developers, offering a reliable and scalable solution for building and managing mobile and web applications. One of its key strengths lies in its ease of integration and scalability, enabling developers to quickly set up and configure backend services without the need for extensive infrastructure management. In this project, we utilize the Firebase Realtime Database to facilitate seamless synchronization of data between mobile devices and the ESP32 development board in real-time. This functionality is crucial for our indoor positioning system, which requires live updates.

4.3 System Components Interaction Operations

The indoor positioning system operates through intricate interactions between its core components. Firstly, the infrared transmitter emits signals encoded with location information, which are subsequently captured and decoded by the infrared receiver. This exchange enables the precise determination of location within the designated area. The interpreted address data obtained by the receiver is then seamlessly transmitted to the Firebase Realtime Database, ensuring real-time storage and accessibility of location information. Concurrently, the mobile application initializes the indoor map and establishes a robust connection with the Firebase Realtime Database. Through continuous retrieval of address data from the database, the application dynamically displays the respective locations on the indoor map, offering users up-to-date insights into their positions. These cohesive interactions between the transmitter, receiver, database, and mobile application underpin the system's efficacy in delivering accurate and infrared real-time indoor positioning capabilities.

CHAPTER 5

SYSTEM IMPLEMENTATION

5.1 Hardware Setup

The hardware components employed in the proposed system include the infrared transmitter, infrared receiver, and the Arduino ESP32 Development Board. Why choose the ESP32 over the ESP8266? The ESP32 serves as the successor to the ESP8266, offering notable enhancements. In comparison to the ESP8266, the ESP32 features an additional CPU core, faster Wi-Fi capabilities, a greater number of GPIOs, and support for Bluetooth 4.2 and Bluetooth Low Energy. Furthermore, the ESP32 is equipped with touch-sensitive pins that facilitate waking up the board from deep sleep and boasts a built-in hall effect sensor. Despite the slightly higher cost of the ESP32 compared to the ESP8266, it remains a preferred choice for development due to its robust capabilities [16].

Next, prior to establishing the infrared positioning system, it is essential to examine the model of the Arduino ESP32. Different versions of this board exist with varying numbers of available pins (30, 36, and 38), although all boards function in a similar manner. The GPIO pins will fulfill varying functions depending on the specific program in use. Additionally, understanding the model of the ESP32 board is crucial for board selection when uploading sketches to the board in Arduino IDE.

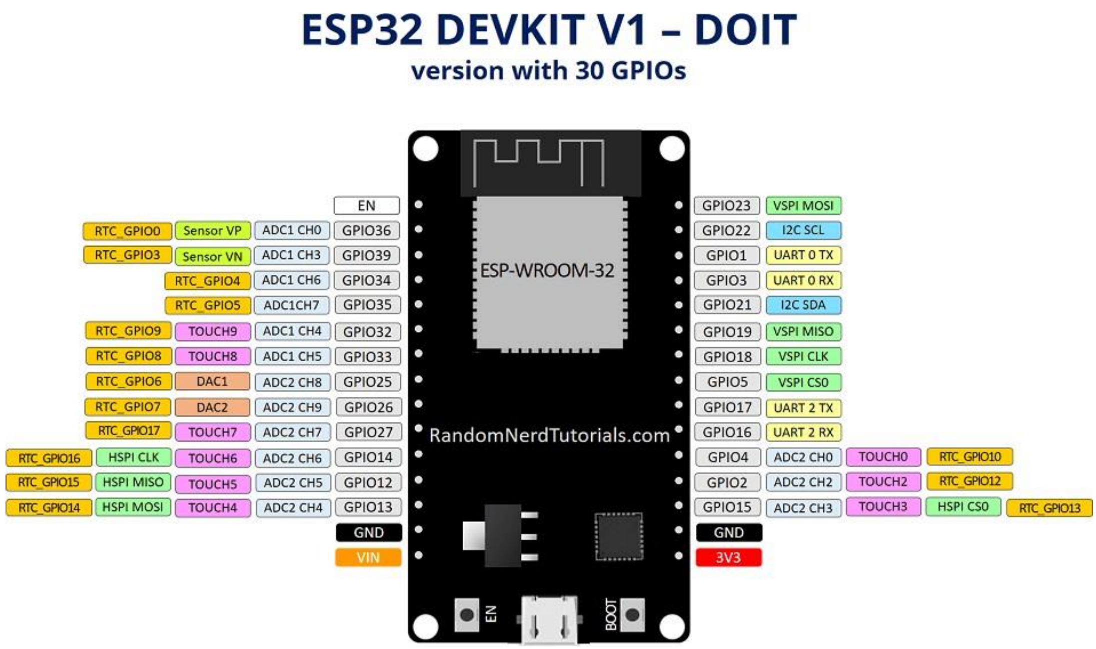

Figure 5.1 ESP32 DEVKIT V1 – DOIT [17]

In this project, I opted for the ESP32 DEVKIT V1 DOIT version, featuring 30 GPIOs, as my development board. This choice is recommended for beginners [16]. The GPIOs details of the selected ESP32 board are displayed in Figure 3.3. Next, the ESP32 board comes with all the necessary circuitry to power the chip, providing a USB-B interface for users to power up. The most common method is to directly connect it to the laptop, forming a circuit for easy code uploading.

Additionally, it is crucial to highlight the infrared receiver sensor module and infrared transmitter module, which features three interfaces for connection to the ESP32 board: GND, VCC, and DAT/OUT. GND corresponds to the ground pin, linked to the GND pin on the ESP32 board. To power the infrared receiver, connect its VCC pin to the power supply rather than directly to the 3V3 pin of the ESP32. This aligns with the VIN pin (5V) on the ESP32 board, providing the necessary current for the infrared receiver's operation. The final interface, DAT/OUT, serves as a digital output and should be linked to any GPIO pin supporting both internal pull-up and pull-down resistors. In our case, we have used the 'D5' as receiver pin number and 'D4' as sender pin number. These connections are made using female-to-male connectors, ensuring convenience and ease of setup. The connection showed in Figure 3.4 and Figure 3.5.

Figure 5.2 Connection between Infrared Receiver with ESP32 Development Board

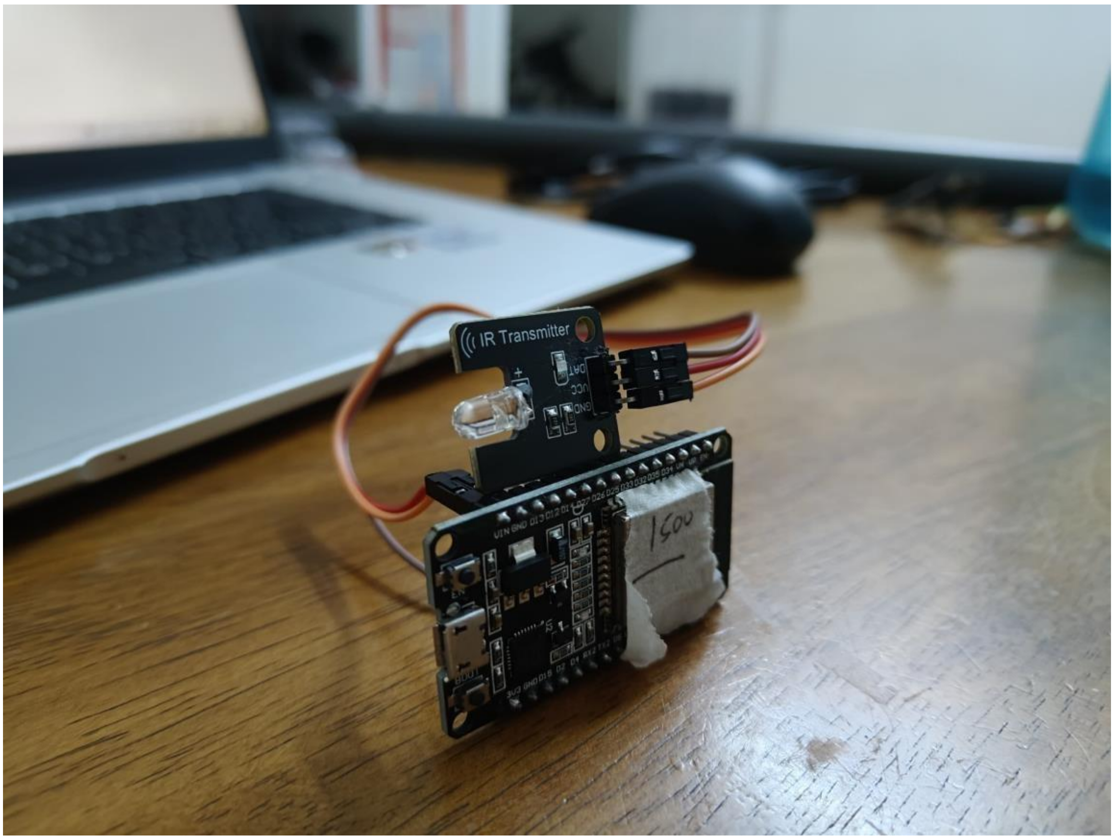

Figure 5.3 Connection between Infrared Transmitter with ESP32 Development Board

Once the infrared receiver and transmitter is connected to the ESP32 development board, the next step involves linking the ESP32 to the laptop and initiating the sketch upload process. This configuration aims to enable the infrared receiver to interpret signals carrying distinct identification strings (address) sent by infrared transmitter.

5.2 Software Setup

The software involved in our project is Arduino IDE. It's important to note that the USB cable used to connect the ESP32 development board to our laptop must be a data cable capable of transferring data, not just a charging cable. When the ESP32 development board is connected to our laptop, we need to select the appropriate model for the ESP32 development board based on the information mentioned earlier. In this case, the model should be ESP32 DEVKIT V1 – DOIT. If the selected board in Arduino IDE is not compatible with the ESP32 model, the sketch will fail to upload to the board. For beginners who have just installed the Arduino IDE from the internet, it's necessary to install the ESP32 library either from the built-in library manager or include the library into the library manager first, as the Arduino IDE does not provide ESP32 board selection initially.

After installing the library, we will initiate the process of programming by delving into the creation of the specific code we desire for our project. In this project, our objective is to enable the infrared receiver to successfully read and decode the signal received from the infrared transmitter. Therefore, conducting trials to receive and interpret the signal string from the transmitter is essential for us to understand the specific meaning of each signal.

To evaluate the functionality of our proposed infrared positioning system, we'll first direct the output that received by the receiver to the serial monitor, a window within the Arduino IDE that displays real-time data. This aids in assessing the system's performance and decoding the infrared signal transmitted by the infrared transmitter. After that, we'll utilize the ESP32's WiFi capabilities to connect the ESP32 to the Wi-Fi network, enabling the transmission of interpreted signal data from the receiver to the Firebase Realtime Database.

Following this, we'll develop a mobile application using the Flutter framework as our display tool. Inside Visual Studio Code, we have done the Flutter configuration (plugins) to enable the mobile application development by following the instruction in the Flutter online documentation. After that, we initiated a Flutter application to showcase a indoor map within the app. Additionally, we'll continuously retrieve data (such as transmitters addresses) stored in the Firebase Realtime Database. This data will be used to place a specific red marker on the indoor map, verifying the location of the receiver.

To utilize the Firebase service, we must first create a Firebase project in the Firebase Console. Following that, we need to register our application in Visual Studio Code with Firebase and integrate the Firebase SDK into it, which involves passing the Firebase project configuration. Subsequently, we can initialize the Firebase service in our application. To further utilize the Firebase Realtime Database, we need to define the Realtime Database rules to control who has read and write access to our data. Finally, we can commence using the Realtime Database to store and retrieve data by employing Firebase SDK methods in Flutter to interact with the database.

5.3 Setting and Configuration

As depicted in Figure 5.4, the Infrared IPS setup consists of eight PVC pipes, with four pipes used for standing and the remaining four pipes serving as a frame cover on top. The defined height of the indoor positioning system setup is approximately 110 cm, as shown in Figure 5.6. Additionally, two power banks are attached to PVC pipes to supply power to the four transmitters positioned at different locations denoted by four red circles in Figure 5.4.

A power bank is mounted atop the remote control car to function as a power source for the ESP32 with the infrared receiver. The remote control car symbolizes a user in real-life scenarios who holds the infrared receiver. Moreover, it is maneuvered to traverse within the indoor positioning system setup.

Figure 5.4 Indoor Positioning System Setup

Figure 5.5 Remote Control Car with Infrared Receiver

Figure 5.6 Height of the IR IPS

Moreover, for Firebase Realtime Database, we should first make sure the 'read' and 'write' rules in the Firebase Realtime Database are both configured to true to ease implementation during development.

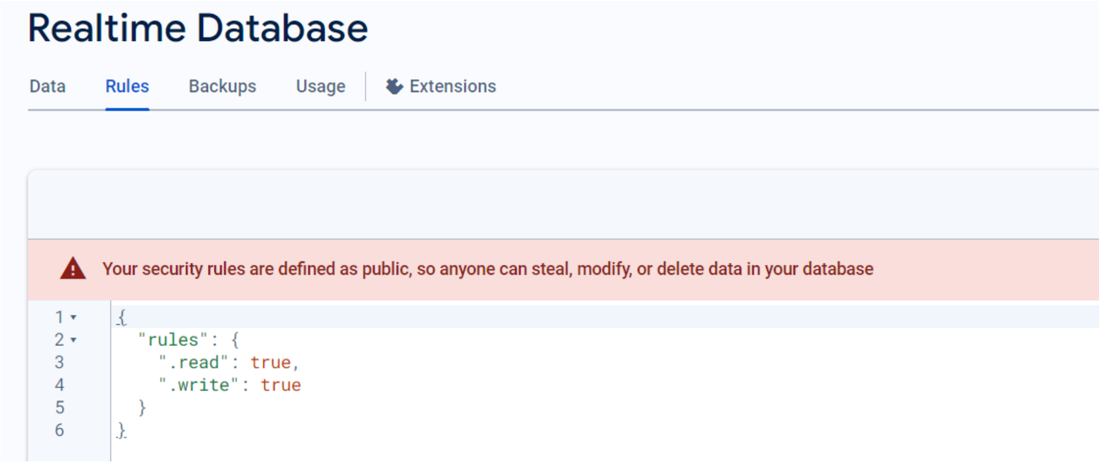

Figure 5.7 Rules of Firebase Realtime Database

In addition, we need to append the path '/data' to the original reference URL, a URL that acts as a key to connect to the service of the realtime database. This ensures that there is a specific location to store and retrieve the address data decoded by the receiver.

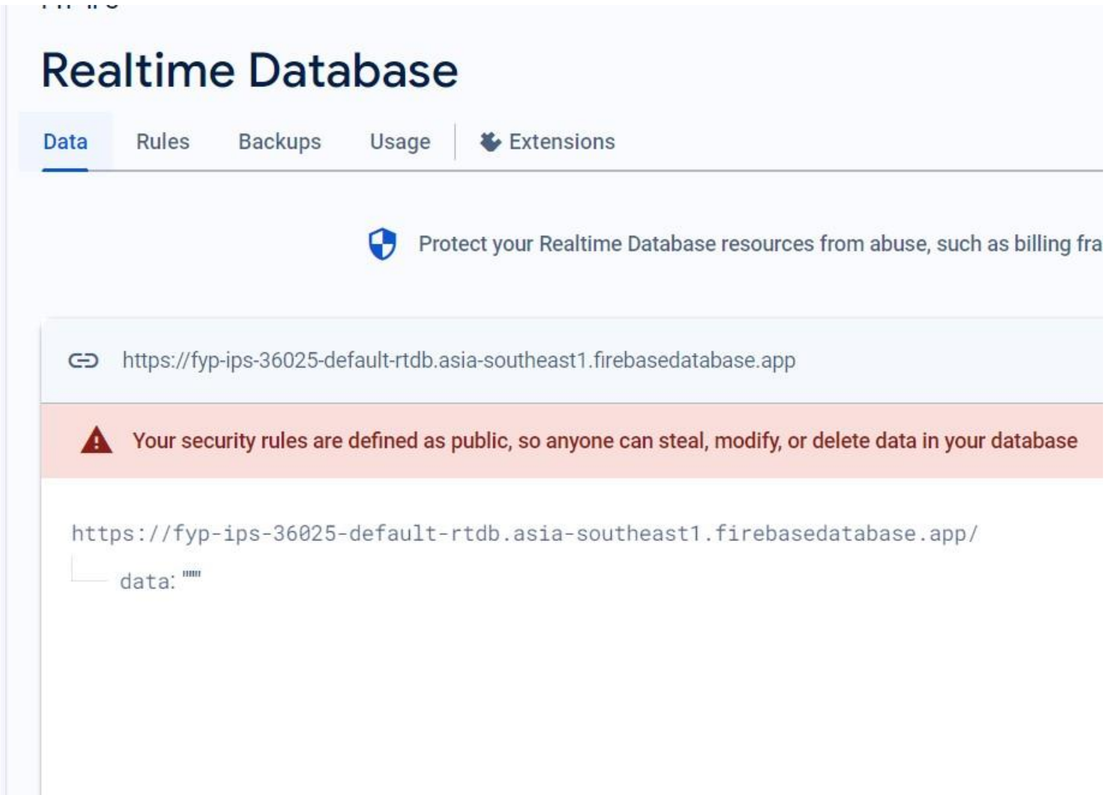

Figure 5.8 Path Added of Reference URL

5.4 System Operation (with screenshot)

Figure 5.9 depicts the indoor map displayed within the mobile application using the Flutter framework. The application continuously retrieves data from the Firebase Realtime Database and display it onto the top of the indoor map. Upon retrieving the data, the mobile application conducts a validation check and marks a red point on specific coordinates corresponding to the location determined by the data value (address of the transmitter).

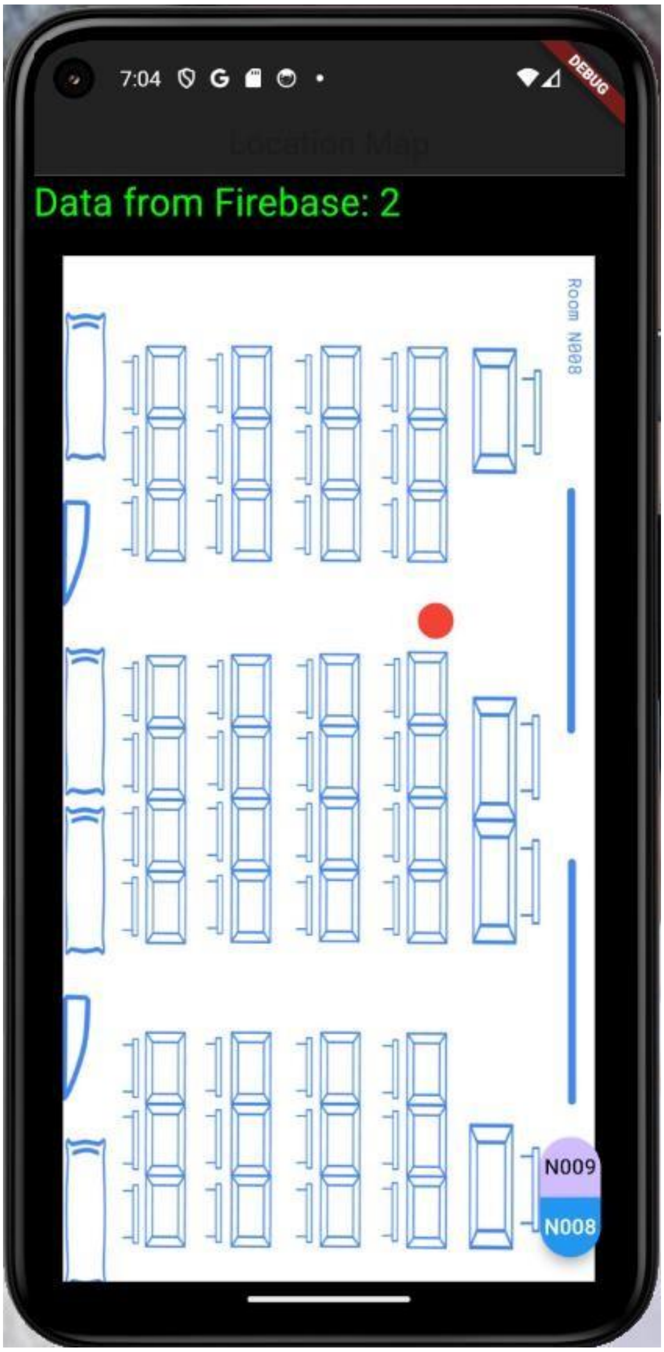

Figure 5.9 Flutter Mobile Application with Indoor Map Operation

Figure 5.10 showcases the decoded signal received by the infrared receiver. The infrared signal is successfully identified as the NEC protocol, and it is being decoded, carrying both the address and command emitted from the transmitter.

```
12:16:06.255 -> Protocol=NEC Address=0x3 Command=0xD0 Raw-Data=0x2FD0FC03 32 bits LSB first
12:16:06.288 -> Send with: IrSender.sendNEC(0x3, 0xD0, <numberOfRepeats>);
12:16:07.032 ->
12:16:07.440 -> Protocol=NEC Address=0x3 Command=0xF0 Raw-Data=0xFF0FC03 32 bits LSB first
12:16:07.440 -> Send with: IrSender.sendNEC(0x3, 0xF0, <numberOfRepeats>);
12:16:08.198 ->
12:16:08.571 -> Protocol=NEC Address=0x3 Command=0x10 Raw-Data=0xEF10FC03 32 bits LSB first
12:16:08.571 -> Send with: IrSender.sendNEC(0x3, 0x10, <numberOfRepeats>);
12:16:09.396 ->
12:16:10.807 -> Protocol=NEC Address=0x3 Command=0x50 Raw-Data=0xAF50FC03 32 bits LSB first
12:16:10.851 -> Send with: IrSender.sendNEC(0x3, 0x50, <numberOfRepeats>);
```

Figure 5.10 Infrared Receiver Operation

Furthermore, the transmitter is operating by continuously sending the standard NEC protocol which carry the data of address, commands, and number of repeats, as depicted in Figure 5.11.

```
22:55:49.433 -> Send now: address=0x01, command=0xB0, repeats=2
22:55:49.433 -> Send standard NEC with 8 bit address
22:55:50.315 ->
22:55:50.315 -> Send now: address=0x01, command=0xD0, repeats=2
22:55:50.315 -> Send standard NEC with 8 bit address
22:55:51.215 ->
22:55:51.215 -> Send now: address=0x01, command=0xF0, repeats=2
22:55:51.215 -> Send standard NEC with 8 bit address
22:55:52.095 ->
22:55:52.095 -> Send now: address=0x01, command=0x10, repeats=2
22:55:52.095 -> Send standard NEC with 8 bit address
```

Figure 5.11 Infrared Transmitter Operation

5.5 Implementation Issues and Challenges

5.5.1 Self-Study for Hardware Simulation

As a computer science student with limited expertise in hardware simulation, immersing myself in the setup of an infrared system initially posed a significant challenge. Initially, I grappled with the uncertainty of which components to acquire for the system setup. The process of comprehending the necessary hardware, its functionalities, and the intricacies of connecting them to establish a tangible system proved time-consuming. To address this issue, I turned to online tutorials and documentation that offered step-by-step guidance for configuring infrared-based systems. Additionally, seeking guidance from Dr. Ooi, who possesses expertise in hardware simulation, has been instrumental in enhancing my understanding of these hardware components. Through a combination of independent exploration and expert advice, I am gradually gaining confidence in navigating the complexities of hardware simulation for infrared systems.

5.5.2 Uploading and Troubleshooting Sketches for Arduino IDE

Uploading sketches to the Arduino IDE occasionally poses a challenge, often requiring the simultaneous pressing of the reboot or reset button on the connected board. This process is particularly common when working with certain Arduino-compatible microcontrollers while I have no idea about it. The difficulty arises as precise timing is crucial; the upload must coincide with the initiation of the board's bootloader (press the “boot” button when uploading process start). While this extra step can be a source of frustration, it serves as a workaround to ensure successful firmware uploads. To tackle this issue, I explored the Arduino Forum and conducted a search to find solutions to a similar problem. Navigating this process becomes a skill for Arduino enthusiasts, underscoring the importance of understanding the intricacies of specific boards and their compatibility with the Arduino IDE for a smoother programming experience.

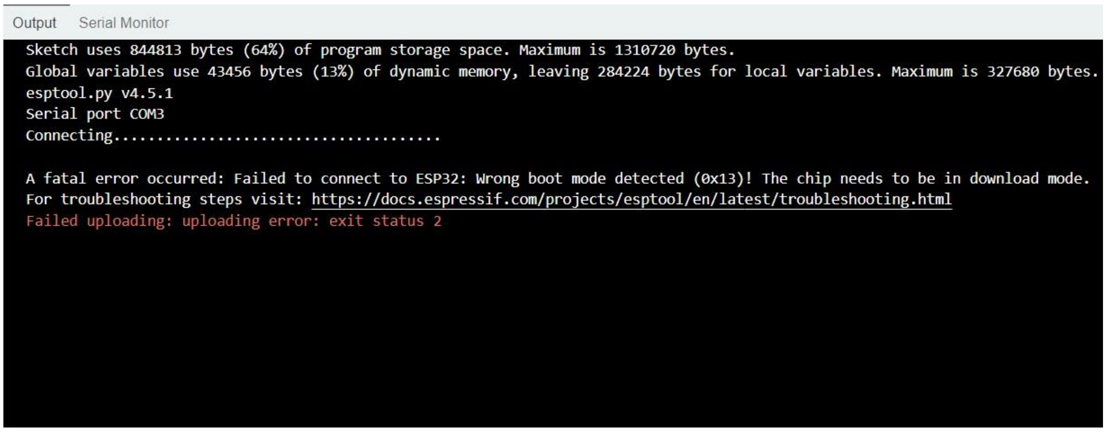

Figure 5.12 Error showed when not pressing “boot” during uploading sketch

5.5.3 Wrongly Power Supply for Both Infrared Transmitter and Receiver

Initially, the performance of the infrared transmitter and receiver in this project was found to be suboptimal when the signals were received by the infrared receiver. Due to the incorrectly determined power supply, the effective range of the receiver for receiving the infrared signal was limited to an exceptionally short distance of 3-5 cm, which was highly unfavorable. Furthermore, the angle requirements were challenging, necessitating precise alignment of the transmitter's bulb with the receiver's head, a condition that did not meet our expectations. To address these limitations, I attempted to debug the problem and successfully identified the incorrect power supply issue. I resolved it by connecting the VCC pin of the infrared transmitter to the VIN pin of the ESP32, which can provide a 5V voltage, instead of the 3V3 pin, which only provides a 3V voltage to the both transmitter and receiver.

5.6 Concluding Remark

In conclusion, Chapter 5 elucidates the meticulous hardware and software setup integral to the implementation of the proposed ultra-low-cost infrared indoor positioning system. Through careful selection of components and thorough configuration processes, the system has been effectively established to facilitate accurate localization within indoor environments. The utilization of the ESP32 development board offers enhanced capabilities over its predecessor, the ESP8266, ensuring robust performance and compatibility with the project requirements. Additionally, the software setup involving Arduino IDE and Firebase Realtime Database integration has enabled seamless communication and data transmission between the infrared receiver and the mobile application, further enhancing the system's functionality. Despite encountering challenges such as hardware simulation complexities and sketch uploading issues, diligent troubleshooting and resource utilization have facilitated the resolution of these obstacles, underscoring the importance of adaptability and perseverance in project development. Moving forward, the successful implementation of the infrared indoor positioning system sets the stage for comprehensive system evaluation and validation, paving the way for its practical deployment in various indoor settings.

Chapter 6

SYSTEM EVALUATION AND DISCUSSION

6.1 System Testing Setup and Result

6.1.1 Accuracy Testing

I conducted accuracy testing on the indoor positioning system setup to assess its accuracy. The results of the testing revealed the effectiveness of the novelty introduced in this project. As illustrated in Figure 6.1, the testing demonstrated that when the receiver traversed the designated black line marked by masking tape, the location displayed in the mobile application promptly and accurately transitioned from location 1 to location 2 as depicted in Figure 6.2. This outcome signifies that the received signal data from the transmitter effectively discerns the receiver's location within a narrow range, surpassing the capabilities of other indoor positioning technologies such as WiFi-Based and Bluetooth-Based IPS, which fail to achieve similar accuracy.

Figure 6.1 Accuracy Testing

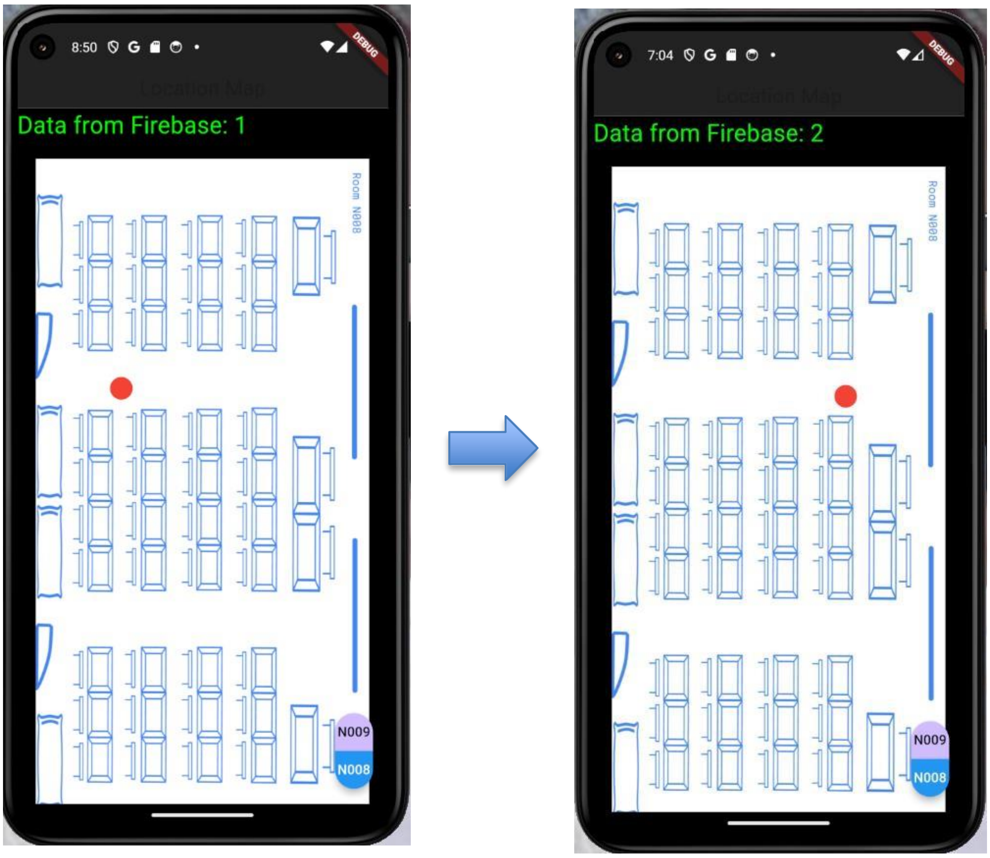

Figure 6.2 Changing of Location After Passing Through A Distinction Line

6.1.2 Range Testing

Furthermore, I conducted range testing on the proposed indoor positioning system to evaluate the infrared receiver's capability to receive and decode signals transmitted from the transmitter. With the setup's height set to 110 cm, the receiver, affixed atop the remote control car, demonstrated an effective range of approximately 70 cm. This assessment provides valuable insights into the system's operational range and performance under specified conditions.

Figure 6.3 Range Testing

6.1.3 Locking Time Analysis

The locking time refers to the duration it takes for the system to establish a stable and accurate connection between the infrared transmitter and receiver, enabling precise localization of objects or users within the designated area. The locking time of the proposed IPS can achieve approximate thirdteen to fifteen milliseconds, which is faster than the WiFi-Based and Bluetooth-Based IPS which required few milliseconds to several seconds. This is basically because the infrared red had the direct line-of-sight characteristic, while WiFi-based and Bluetooth-based indoor positioning is using the radio interferences, contribute to quicker response times in infrared communication. The testing is done by calculating the difference between the current time when the receiver successfully decode the received signal and the locking time when the receiver receives the signal.

```
13:51:56.068 -> Protocol=NEC Address=0x3 Command=0xD0 Raw-Data=0x2FD0FC03 32 bits LSB first
13:51:56.068 -> Send with: IrSender.sendNEC(0x3, 0xD0, <numberOfRepeats>);
13:51:56.114 -> currentTime:
13:51:56.114 -> 1269386
13:51:56.114 -> Locking Time: 15.0000 milliseconds
```

Figure 6.4 Example of Testing Locking Time

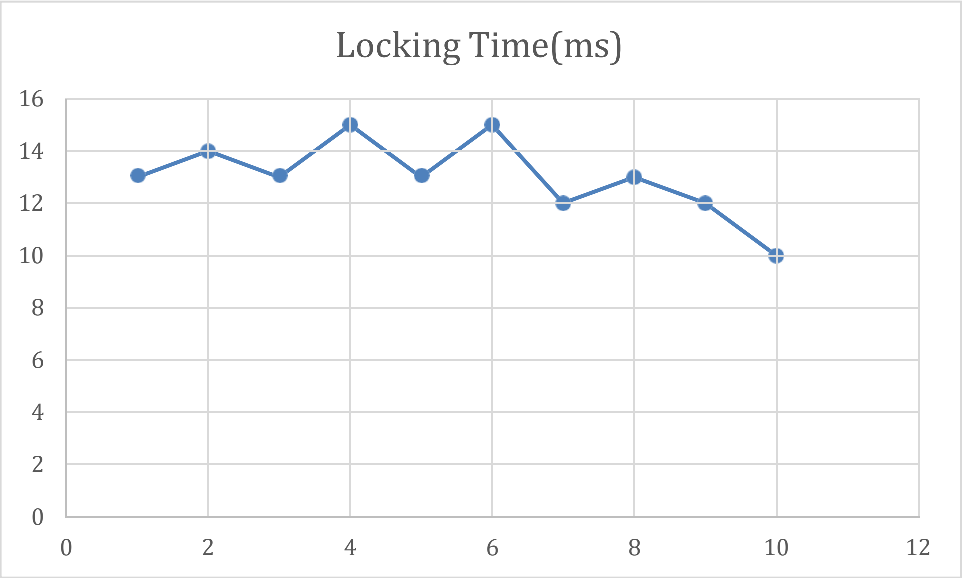

Figure 6.5 Locking Time Scatter Plot

6.1.4 Robustness Testing

For robustness testing, I conducted system tests in various environments, including ambient lighting and no lighting conditions. The results indicated that the system remained resistant to environmental interference, maintaining consistent accuracy and performance regardless of lighting conditions.

Figure 6.6 Ambient Lighting Condition

Figure 6.7 No Lighting Condition

6.2 Project Challenges

In this project, one of the major challenges encountered was devising the overall flow of the proposed indoor positioning system. This involved constructing the conceptual framework for how to effectively display the interpreted signal data from the ESP32 processing unit to end users. Additionally, determining the appropriate components to use for the system design presented another hurdle. Due to the scarcity of similar projects with the same concept, there was a lack of reference points, making testing and debugging processes particularly challenging. Ensuring the functionality of the proposed system required significant effort and troubleshooting. Furthermore, validating the concept of using infrared technology for indoor positioning posed its own set of difficulties. The limited timeframe of approximately 8 months added pressure to the project timeline, making it necessary to work efficiently and prioritize tasks effectively.

6.3 Objective Evaluation

The proposed project has successfully achieved all of its objectives, demonstrating its effectiveness in developing an ultra-low-cost and precise infrared indoor positioning system for practical implementation.

By focusing on harnessing invisible infrared signals, the system has effectively addressed the limitations of widely-used Wi-Fi indoor positioning, ensuring room-level accuracy. Throughout this project, I have developed an infrared indoor positioning system capable of providing room-level accuracy. This was demonstrated by verifying that as the receiver passes through a defined boundary, the received signal accurately changes to the specific address data from specific transmitter in the area.

Moreover, the project has effectively addressed the pervasive issue of radio frequency interference, a common challenge encountered in indoor positioning systems, by strategically leveraging infrared technology. Through rigorous evaluation and testing, the system has proven its capability to determine an object's location within a building accurately. The system would not be affected by the radio frequency interference as it is using the light which depends on the line-of-sight.

Furthermore, the utilization of affordable infrared transmitter and receiver components has made the system economically viable, addressing the high development costs associated with alternative indoor positioning technologies. Additionally, it has opened up opportunities for more widespread use of indoor positioning systems in different practical situations. This achievement marks a significant milestone in the development of reliable and cost-effective indoor positioning solutions.

6.4 Concluding Remark

In conclusion, Chapter 6 highlights the successful implementation and thorough testing of the proposed ultra-low-cost infrared indoor positioning system. Through accuracy testing, range testing, locking time analysis, and robustness testing, the system has demonstrated impressive performance, surpassing other indoor positioning technologies in terms of accuracy, speed, and resistance to environmental interference. Despite facing challenges in conceptualization, component selection, and validation of the infrared technology concept, the project has effectively addressed these hurdles and achieved its objectives within the designated timeframe. The project's contribution to overcoming the limitations of existing indoor positioning systems while remaining cost-effective and accessible marks a significant milestone in the advancement of indoor positioning technology. With its proven effectiveness and affordability, the system holds promising potential for widespread adoption in various practical applications, paving the way for enhanced localization capabilities in indoor environments.

‘

Chapter 7

CONCLUSION

7.1 Conclusion

In summary, this project addresses persistent challenges within indoor positioning systems, proposing that the Infrared Indoor Positioning System (IPS) has the potential to gain global recognition, much like GPS. The distinctive features of the proposed infrared system, characterized by its ultra-low cost and minimal infrastructure requirements, distinguish it from existing solutions burdened by implementation issues, including complex calibration and extensive setup.

Looking ahead, the project envisions the Infrared IPS as a cost-effective and accessible solution with the potential for widespread implementation. By emphasizing room-level accuracy, mitigating interference issues, and prioritizing cost and energy efficiency, the proposed system is poised to bridge the gap between indoor and outdoor positioning technologies. Room-level accuracy is the most emphasized selling point in this project, making it superior to other IPSs. As the project advances, future iterations aim to refine and expand the system's capabilities, making it a versatile and dependable tool for various indoor positioning applications.

At the core of this endeavor is the adoption of infrared technology for localization purposes. The project leverages the line-of-sight characteristic of infrared, effectively addressing issues prevalent in radio-wave-based IPS, particularly interference. The comprehensive setup includes essential hardware components, such as an infrared transmitter, infrared receiver, and the ESP32 development board. These components are managed through the Arduino IDE for software development. The data collected is utilized to display the location inside the indoor map in the mobile application, with synchronization facilitated between Firebase and ESP32.

Furthermore, the project places a strong emphasis on addressing scalability and power consumption, crucial aspects for the sustainability and widespread implementation of the proposed Infrared IPS. The ultra-low cost associated with the system, along with its focus on energy efficiency, enhances its scalability and sustainability, making it a competitive solution in the realm of indoor positioning technologies.

Other than that, through accuracy, range, locking time, and robustness testing, the system has demonstrated its effectiveness and reliability in accurately determining the location of objects within indoor environments. The results underscore the superiority of the infrared technology utilized, surpassing the capabilities of traditional WiFi-based and Bluetooth-based indoor positioning systems. Furthermore, the system's robustness to environmental factors ensures consistent performance across various conditions, enhancing its practical applicability.

Overall, this initiative represents a significant leap forward in the realm of IPS, laying the groundwork for a promising and innovative solution that not only addresses current challenges but also sets the stage for continuous improvement and adaptation to evolving indoor positioning needs.

7.2 Recommendation

Based on the comprehensive analysis and successful implementation of the Infrared Indoor Positioning System (IPS), it is recommended that organizations and stakeholders consider adopting this innovative solution to address their indoor positioning needs. The project's emphasis on room-level accuracy, ultra-low cost, and minimal infrastructure requirements positions the Infrared IPS as a highly competitive alternative to existing indoor positioning technologies burdened by complex calibration and setup processes. Furthermore, the system's scalability, energy efficiency, and robustness to environmental factors underscore its suitability for various indoor environments and applications. As such, investing in the implementation and further development of the Infrared IPS holds significant promise for organizations seeking reliable and cost-effective indoor positioning solutions.

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APPENDICES

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Y3T2	**Study week no.: 2**
Student Name & ID: Khee Chun Seng (2002593)	
Supervisor: Dr. Ooi Boon Yaik	
Project Title: Indoor Positioning System	

1. WORK DONE During this week, I had meet the Dr. Ooi for some problem discussions and continue the development of the infrared positioning system. I also focusing on drawing different diagrams that matched to the proposed system.
2. WORK TO BE DONE In the upcoming week, I plan to complete every diagrams and Chapter 1 and Chapter 2 for the FYP2 report.
3. PROBLEMS ENCOUNTERED I need to perform testing on the configured infrared receivers to check if it can successfully intepreted the signal from infrared transmitter which is time consuming.
4. SELF EVALUATION OF THE PROGRESS I believe I made a good start to the project, establishing a solid foundation for the subsequent development and chapter. The guidance and interaction with my supervisor played a crucial role in shaping the direction of the project.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Y3T2	Study week no.: 4
Student Name & ID: Khee Chun Seng (2002593)	
Supervisor: Dr. Ooi Boon Yaik	
Project Title: Indoor Positioning System	

1. WORK DONE

During this week, I completed all the diagram drawings, including the proposed system model, system block diagram, Entity-Relationship diagram, etc. Additionally, I devoted my efforts to contemplating the real-life system setup.

2. WORK TO BE DONE

I will delve into the idea of setup of the infrared positioning system. Besides, I will start to look into the documentation and configure the Flutter and Firebase for further development.

3. PROBLEMS ENCOUNTERED

No significant problems were encountered during this period.

4. SELF EVALUATION OF THE PROGRESS

Progressing well with the Chapter 1, 2, and 3, I've been able to gather valuable information that will inform the subsequent chapters of the project.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Y3T2	**Study week no.: 6**
Student Name & ID: Khee Chun Seng (2002593)	
Supervisor: Dr. Ooi Boon Yaik	
Project Title: Indoor Positioning System	

1. WORK DONE

Throughout this week, my attention transitioned to integrate the Flutter mobile application and Firebase Realtime Database into my project. I have also confirmed the proposed IPS setup with Dr. Ooi.

2. WORK TO BE DONE

In the upcoming week, I plan to complete the Chapter 4 and Chapter 5 in FYP2 report.

3. PROBLEMS ENCOUNTERED

No significant problems were encountered during this period.

4. SELF EVALUATION OF THE PROGRESS

Continuing with consistent advancement in Chapter 4, I've also commenced the development of the infrared positioning system, marking a significant milestone in this project.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Y3T2	Study week no.: 8
Student Name & ID: Khee Chun Seng (2002593)	
Supervisor: Dr. Ooi Boon Yaik	
Project Title: Indoor Positioning System	

1. WORK DONE
This week, I prepared the PVC pipes and attempted to build a real-life indoor positioning system demo. I keep working on Chapters 4 and 5 in the FYP report 2.
2. WORK TO BE DONE
I plan to complete the development of the infrared positioning system. Then, I will perform testing to evaluate the performance of the IPS built.
3. PROBLEMS ENCOUNTERED
The progress of the setup of the IPS is not going so well, need to find a way to stabilize the building.
4. SELF EVALUATION OF THE PROGRESS
I am content with the progress of my project development as the envisioned infrared system is now materializing and is already operational.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Y3T2	**Study week no.: 10**
Student Name & ID: Khee Chun Seng (2002593)	
Supervisor: Dr. Ooi Boon Yaik	
Project Title: Indoor Positioning System	

1. WORK DONE

This week, I dedicated my efforts to finalizing Chapter 4 and Chapter 5 and started working on Chapter 6, specifically the system testing sections. I conducted a numerous testing to evaluate the performance of the IPS built and modified to perfect the system accordingly.

2. WORK TO BE DONE

In the next few weeks, my primary focus will be on completing the FYP2 report. This entails crafting a compelling and impactful presentation that effectively showcases the key elements of the project.

3. PROBLEMS ENCOUNTERED

No significant problems were encountered during this week.

4. SELF EVALUATION OF THE PROGRESS

I am content with the progress of my project development.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Y3T2	**Study week no.: 12**
Student Name & ID: Khee Chun Seng (2002593)	
Supervisor: Dr. Ooi Boon Yaik	
Project Title: Indoor Positioning System	

1. WORK DONE This week, I started to finalize my FYP2 report and show the IPS demo to the Dr. Ooi to collect his feedbacks.
2. WORK TO BE DONE In the next week, I will be preparing for the FYP2 presentation slides and presentation.
3. PROBLEMS ENCOUNTERED No significant problems were encountered during this week.
4. SELF EVALUATION OF THE PROGRESS The project is now 85% finished and prepared for submission. Reflecting on the development of the project over the past weeks, I am satisfied with the progress achieved and the commitment invested in this endeavor. I eagerly anticipate the evaluation and feedback associated with this project.

Supervisor's signature

Student's signature

POSTER

Faculty of Information Communication and Technology (FICT)

Author: Khee Chun Seng
Supervisor: Dr. Ooi Boon Yaik
Co-Supervisor: Dr. Teoh Shen Khang

INDOOR POSITIONING SYSTEM

This project aims to develop an ultra-low-cost infrared positioning system

Project Scope

- Conduct research on relevant research
- Build and deploy the infrared indoor positioning infrastructure
- Evaluate effectiveness of the proposed solution

Objective

- Overcome the limitations of widely-used Wi-Fi indoor positioning, often falling short in providing room-level accuracy
- Leverage invisible infrared signals to determine an object's location within a building
- To address the common issue of radio frequency interference encountered in indoor positioning systems

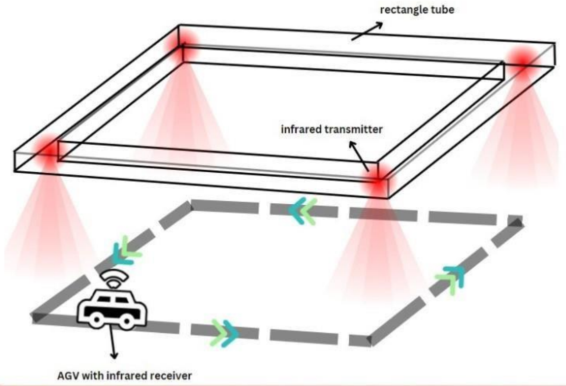
Motivation

- Potential to become a solution that can be implemented worldwide
- Able to perform indoor positioning with lower cost as comparing to other indoor positioning approaches

Contribution

- Reduces the dependence on extensive infrastructure
- The proposed solution is cost-effective and time-efficient
- Able to addresses interference of other IPS

Proposed System Model



Conclusion

- Infrared-based indoor positioning system with infrared transmitter and infrared receiver
- Emphasizing room-level accuracy, mitigating interference issues, and prioritizing energy efficiency

PLAGIARISM CHECK RESULT

FYP2 - NoReferences

ORIGINALITY REPORT

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3	Taiga Arai, Takahiro Yoshizawa, Takuya Aoki, Keiichi Zempo, Yukihiko Okada. "Evaluation of Indoor Positioning System based on Attachable Infrared Beacons in Metal Shelf Environment", 2019 IEEE International Conference on Consumer Electronics (ICCE), 2019 Publication	1%
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ID Number(s)	20ACB02593
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Based on the above results, I hereby declare that I am satisfied with the originality of the Final Year Project Report submitted by my student(s) as named above.

Signature of Supervisor

Name: Dr. Ooi Boon Yaik

Date: 25/4/2024

Signature of Co-Supervisor

Name: Dr. Teoh Shen Khang

Date: 26 April 2024

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