DRAYB N' ARAYB: AN IoT REAL-TIME PARKING MANAGEMENT SYSTEM USING DIJKSTRA'S ALGORITHMS FOR DIVINE WORD COLLEGE OF LEGAZPI

A Thesis Presented to

the Faculty of the Undergraduate Program

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In Partial Fulfillment

of the Requirements for the Degree

BACHELOR OF SCIENCE IN COMPUTER SCIENCE

By:

REY GABRIEL L. LITERAL

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RECOMMENDATION FOR THESIS FINAL DEFENSE

In partial fulfillment of the requirements for the degree Bachelor of Science in Computer Science, this Thesis entitled, "**DRAYB N' ARAYB: AN IoT REAL-TIME PARKING MANAGEMENT SYSTEM USING DIJKSTRA'S ALGORITHMS FOR DIVINE WORD COLLEGE OF LEGAZPI"** prepared by **Rey Gabriel L. Literal** is hereby submitted to the Thesis Committee for consideration and approval.

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In partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science, this Thesis titled, "**EmergenStay: Evacuee-based Prioritization Room Allocation System Using Optimized Genetic Algorithm for Barangay Matanag**" prepared by Gio Andrei E. Padua is hereby considered and endorsed for Final Defense.

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RESULT OF THE FINAL DEFENSE

Project Title : DRAYB N' ARAYB: An Iot Real-Time Parking Management System using Dijkstra's Algorithm for Divine Word College of Legazpi

Researcher : Rey Gabriel L. Literal

Place: SOECS Conference Room **Date:** September 12, 2024 **Time:** 9:00am - 10:30am

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Project Title : DRAYB N' ARAYB: An Iot Real-Time Parking Management System using Dijkstra's Algorithm for Divine Word College of Legazpi

Researcher : Rey Gabriel L. Literal

Degree Program : Bachelor of Science in Computer Science

Final Defense Completed on : September 12, 2024

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EXECUTIVE SUMMARY

Project Title : DRAYB N' ARAYB: An Iot Real-Time Parking Management System using Dijkstra's Algorithm for Divine Word College of Legazpi

Researcher : Rey Gabriel L. Literal

Keywords : Real-time, Parking Management System, Dijkstra's Algorithm, Internet of Things (IoT)

Traffic congestion posed a significant dilemma in numerous urban areas, stemming from issues like signal malfunction, and subpar traffic administration. This concern has adverse effects on the economy, the environment, and the general standard of living. An IoT Real-Time Parking Management System Using and Dijkstra's Algorithm for Divine Word College of Legazpi" sought to address this problem. The users' overall parking experience is improved by this system's real-time parking spot management and monitoring. By utilizing Arduino technology, the device effectively kept track of the available parking. DRAYB N' ARAYB improved the entire parking experience by optimizing vehicle routing to the shortest way to the school grounds by utilizing Dijkstra's Algorithm. A web application developed on Node-RED complemented the system by giving customers real-time parking availability information. Additionally, the users conveniently obtained parking information while on the road with the Remote-Red mobile app. This integrated solution not only alleviated parking congestion but also promoted efficient space utilization, making it a vital tool for the campus community.

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R.G.L.L.

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INTRODUCTION

PROJECT CONTEXT

Traffic congestion poses a significant dilemma in numerous urban areas, stemming from issues like signal malfunction, and subpar traffic administration. This concern has adverse effects on the economy, the environment, and the general standard of living. Parking management problems are a common issue in cities, especially in large cities where there is limited parking space. Inadequate enforcement systems contribute to poor parking conditions (Shao, 2023). Addressing traffic congestion and parking management concerns can help to advance numerous SDGs Goal 9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation and Goal 11 Make cities and human settlements inclusive, safe, resilient and sustainable. By fostering sustainable development, promoting economic growth, safeguarding the environment, and improving quality of life in urban areas (THE 17 GOALS | Sustainable Development, 2015).

According to automotive traffic studies, cruising drivers looking for parking account for around 30% of traffic in crowded urban areas (Nawaz et al., 2013). Finding a spot can be time-consuming, leading to traffic congestion. The present manual parking method requires drivers to manually look for open places. This can be ineffective and frustrating. The solution is smart parking systems, which use sensors and smartphones to display real-time parking availability. These developments aim to make parking easier to use and more data-driven.

The network of physical items, or "things," that are implanted with sensors, software, and other technologies in order to communicate and exchange data with other devices and systems over the internet, is known as the Internet of Things (IoT)

(Accelerate Your Operations with IOT, 2024). These gadgets range from simple household objects to sophisticated industrial instruments. IoT is being used by businesses across many industries to boost productivity, provide better customer service, make better decisions, and add value to their enterprise (Kinza Yasar & Gillis, 2024).

Real-time data refers to data that is displayed in its original form as it is gathered. The handling of real-time data is widely accepted and prevalent in emerging technologies such as mobile applications. Contrary to traditional data storage practices, real-time data is not retained or archived, but rather expeditiously transmitted to the intended recipient (Rouse, 2018). Real time transferring the information conditions of the parking spaces to a cloud platform.

Greedy Algorithms, such as Dijkstra's Algorithm, focus on making the locally best option at each stage in order to obtain a globally optimal solution (shortest path) in the end (Cuervas et al., 2017). Consider exploring a maze. At each junction, these algorithms select the neighboring tunnel with the lowest cost (distance in this case) and create the path in stages . They are efficient in static conditions because they only examine the immediate cost and ensure that the absolute shortest path is found using the defined edge weights. However, they are unable to respond to dynamic changes (Dijkstra's Algorithm, 2023).

The discrepancy between the average parking demand and the effective parking supply is known as parking adequacy. When the value is positive, it is called "surplus," and when the value is negative, it is called "deficit" (Cantila, 2018). As the populace expands, the quantity of automobiles on the thoroughfare concurrently increases, giving rise to traffic congestion, extended periods of travel, and amplified fuel consumption (Kaur & Kamboj, 2022). Since a car needs to park at every destination, parking is one of the key elements of a transportation system. Parking issues may arise when there is less parking available in a given area than there is demand for parking (Trinidad & Cantila, 2019). Management of parking spaces in a parking area comprising a plurality of zones (Jae Kyu Suhr & Ho Gi Jung, 2014). As a result, well-designed parking management solutions are required to efficiently allot parking spaces to cars, particularly in busy urban locations (Errousso et al., 2022). With the massive expanding flood of population in industrialized, industrially and technologically sound urban areas, there is an urgent need to make the cities smart (Telles & Meduri, 2017). As traffic congestion worsens year after year in metropolitan regions, communities look for ways to improve traffic performance and lessen their environmental impacts (Jakob & Menendez, 2020).

Parking management is the ongoing process of adopting and implementing parking rules in order to put strategies into action (Tua et al., 2022). Finding a public parking space is frequently challenging and generates issues for both drivers and citizens due to the enormous number of vehicles that are continuously trying to enter congested locations in cities. In this situation, vehicles need to be guided using procedures that find the best way from one point to another. The majority of the literature's contributions are routing strategies that consider many factors in order to determine the best path necessary to locate a parking spot (Diaz et al., 2020). The current system of parking lot slots for accommodating vehicle owners is primarily done manually. Cars are arriving in large numbers, resulting in a long, painful line merely to park (Luciano et al., 2023). Drivers are well aware of the difficulty in locating parking in any commercial district. Parking puts them behind schedule due to inefficient parking systems (Dichoso et al., 2022). Because of the remarkable advancement in the automobile sector and the growth of the urban population, the number of vehicles is increasing, posing parking issues. Intelligent parking management systems provide an ideal option for discovering empty parking spaces, allowing drivers to easily find their car parking space (Shimi A. et al., 2020).

Urban parking is a major hurdle, causing wasted time, traffic congestion, and pollution due to inefficient search patterns. As cities grow and car ownership increases, these problems worsen. Smart parking systems offer a promising solution by optimizing space allocation, reducing search times, and improving traffic flow, ultimately leading to a more sustainable urban environment.

In recent decades, the number of drivers is rapidly increasing, needing extra parking places. The significant increase in vehicles and the population growth due to urban area development have been considered as a challenge for the smart city in recent years (Midaoui et al., 2022). Cruising for parking indicates a loss of efficiency for the personal vehicle. It wastes time and fuel, exacerbates traffic congestion, and increases pollution emissions (Ferreira & De Abreu E Silva, 2017). A university campus can be considered a small city and it usually undergoes the same parking problems encountered by smart cities (Jhugroo et al., 2021). In a fast increasing world where vehicles are an essential commodity, obtaining a parking spot has become one of the most pressing concerns in our daily lives, frequently generating traffic congestion during peak hours due to increased vehicle density (Vankamamidi, 2021b). The software was used for the management, control, reporting, and operation of parking lots (Charles, 2022). Thus, searching for available parking spaces becomes a daily challenge for most drivers. The problem is getting worse in the open space parking areas in public places such as Campus Parking Space: when unauthorized vehicles dominate the spaces that are initially allocated for their staff.

Consequently, this unwanted scenario may affect productivity (Neo Wei Sheng et al., 2022). The adoption of radio frequency identification is constantly expanding

(Antony, 2022). Because of the increased number of vehicles, it is vital to choose a parking spot in close proximity to prevent traffic congestion and make the most efficient use of space (Aravindh & Arunkumar, 2020). As automobile ownership in the Philippines has increased, so has the demand for parking spaces. This is a problem worth tackling because countless drivers have encountered it, particularly in urban regions where vehicular traffic is common (Balmes et al., 2022). Parking spots have grown increasingly incorporated into our daily lives, especially in urban areas (Blancaflor et al., 2023). It has a significant impact on personal endeavors due to queues, extended wait times, and difficulty locating parking spaces (Gumasing & Atienza, 2018). One of the current services required for any smart city is the availability of adequate parking spots to ensure smooth and easy traffic flow (Jemmali et al., 2022). The current case does not make it simple to find a free parking space. That happens when drivers access the parking area freely (Jiang et al., 2021). To reduce to the minimum the time that the consumers in the search of the parking lot take up. The system under study is a big time saver for the users service and also can effectively solve the existing issues in parking for the management of dense cities (D et al., 2023).

DESCRIPTION OF THE EXISTING SYSTEM

The current parking system at DWCL operated on a "First Come, First Served" basis. The DWCL parking entry process involved a queue system. Drivers upon arrival queue and wait for their turn to proceed through the security checkpoint. Security personnel verified the car pass of each vehicle, security personnel visually assessed the parking lot or relied on manual updates through their colleagues to determine parking availability inside the campus. For DWCL personnel with valid identification, priority is given for entry and they are directed towards the reserved parking areas. This is where the "First Come, First Served" basis applied. If a vehicle had a valid car pass and the parking lot was fully occupied , the security personnel denied the students' entry at the campus parking area.

DESCRIPTION OF THE SYSTEM

The proposed prototype is an innovative parking management system that operates in real-time and incorporates Dijkstra's Algorithm. Its primary objective is to effectively tackle the challenges associated with locating parking spaces within Divine Word College of Legazpi (DWCL) Campus, the task, which is frequently demonstrated to be a laborious endeavor, consisted of informing drivers about the availability, or unavailability of parking spaces within the campus premises. By undertaking this initiative, the researcher aspires to assist the students and the faculty members in arriving punctually for their scheduled engagements. Moreover, this system ensured continuous monitoring for the detection of unoccupied parking spaces in real-time. To achieve this, the system leveraged an IoT technology that wirelessly transmitted information between a hardware and the user system.

STATEMENT OF THE PROBLEM

This study identified the challenges encountered by the students and the faculty members in parking their respective vehicles situated in the premises of Divine Word College of Legazpi (DWCL) Specifically, this study sought answers to the following sub-problems.

1. What are the problems encountered by the drivers in terms of:
    a. Finding Real-time parking availability;
    b. Optimizing shortest path to campus; and
    c. Parking Management?

2. What algorithms to be used in terms of:
    a. Pathfinding?
3. What are the features of the proposed system entitled, “DRAYB N’ ARAYB: An Iot Real-Time Parking Management System using Dijkstra’s Algorithm for DWCL”
4. How will the proposed system satisfy the following quality characteristics of ISO 25010 in terms of:
    a. Compatibility;
    b. Reliability;
    c. Usability; and
    d. Maintainability?

OBJECTIVES

The major goal of this project is to reduce waiting time and traffic flow and to know when the campus parking area is already occupied. The proposed project along with the algorithm aimed to:

1. To conduct a comprehensive analysis of DWCL campus and its parking spaces and to enhance driver’s experience in terms of providing real-time parking availability and to lessen to the time in searching and in optimizing the shortest path in guiding the students and the faculty members with vehicle going to the closest vacant space using pathfinding algorithms and enhancing efficiency to reduce congestion, and to improve parking management by strictly enforcing designated parking zones to DWCL clients.

2. To utilize Dijkstra's algorithm in guiding the DWCL students and faculty members using the shortest path in going to the campus parking area.

3. To develop a system that provides a user-friendly mobile online application

displaying real-time parking availability, with integration of IoT technology that transmit in real-time, data analysis for availability, pathfinding to the shortest path to the parking area and to determine vacant spaces.

4. To adhere to the ISO 25010 assessment tool in terms of compatibility, reliability, usability and maintainability.

PURPOSE AND DESCRIPTION

The DWCL South Campus proposed Real-Time Parking Management Prototype with the Integration of an IoT Technology, Dijkstra's Algorithm will be beneficial to the following:

DWCL. The prototype enhances the reputation of the school as an institution committed to innovation and efficiency in campus management, thus attracting potential students and stakeholders.

Drivers. With real-time updates on parking space availability, drivers experienced reduced stress and frustration, leading to a more positive campus experience.

Faculty. It helps the school's clientele to improve access to parking spaces, allowing them to arrive punctually doing classes and other academic commitments/ activities.

Students. It benefitted the school's clientele to have easy access to parking, enabling them to focus more on their studies and to arrive on time to their respective classes.

Guards. Security personnel had better control over the parking areas, ensuring smoother traffic flow and enhanced safety and security within the campus.

Researcher. This project provides knowledge in creating research, and a platform to demonstrate problem-solving skills, technical expertise and proficiency in applying algorithms.

Future Researchers. This prototype and algorithm served as a valuable case study for future researchers, providing insights into the practical application of IoT technology and algorithms such as Djkistra's algorithm in parking management systems, thus contributing to advancements in the field. It also serves as a basis for future research.

SCOPE AND DELIMITATION

The prototype is intended for Divine Word College of Legazpi college campus. It provided a user-friendly mobile online application displaying real-time parking availability features of IoT technology. Using Dijkstra's Algorithm, It guided the school's clientele to the shortest path to the campus parking lot for better parking management. To test the effectiveness of the proposed system, ISO 25010 assessment tool to be used in terms of compatibility, reliability, usability and maintainability.

Even if the suggested prototype created the framework for an extensive parking management system, it's critical to define precise parameters for the first stage. It did not include functionalities such as payment or billing system, and reservation or booking system, in order to expedite development and guarantee a functioning core system.

TECHNICAL TERMS

For a clearer understanding of the study the following terms are defined conceptually and operationally.

Dijkstra's Algorithm - This refers to the algorithm for finding the shortest paths between nodes in a weighted graph (Dijkstra's Algorithm, 2023). Dijkstra's algorithm can be employed to find the shortest path from the driver's current location to that available space. A graph search algorithm that finds the shortest path between nodes in a weighted graph. In the context of parking management, this algorithm can be used to determine the optimal route to a vacant parking space based on factors like distance and traffic flow.

Internet of Things (IoT) - This refers to low-cost computing, the cloud, big data, analytics, and mobile technologies. Physical things can share and collect data with minimal human intervention (Accelerate Your Operations with IOT, 2024). IoT with the usage of Arduino and Infrared sensors of parking availability in real-time.

Parking Management - This refers to the strategies, technologies, and policies employed to optimize the use of available parking spaces within a designated area (Isarsoft, 2024). The overall administration and coordination of parking resources within a designated area, including allocation, utilization, and enforcement of regulations.

Path Optimization - This refers to the process of finding the most efficient route for a driver to reach the parking lot (Laith Abualigah & Gul, 2021). The process of determining the most efficient route for a driver to reach an available parking space from their current location within the parking area.

Real-Time Parking Availability - This refers to the ability to see exactly where open parking spots are Available or Occupied (Joshi, 2023). The system's ability to provide up-to-date information on the occupancy status of parking spaces within the parking area.

Chapter 2

DESIGN AND METHODOLOGY

This chapter presented the software development, data gathering techniques, sources of data, and survey results used in designing the system.

SOFTWARE DEVELOPMENT

Figure 1

Rapid Application Development

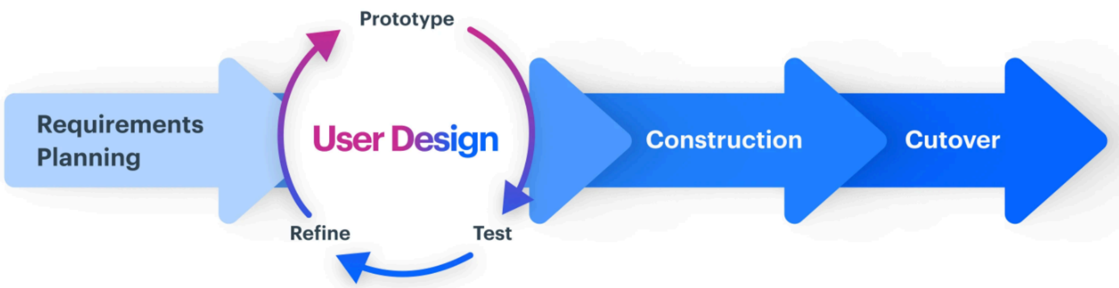


Figure 1 showed the Rapid Application Development (RAD) started in the 1980s, thus it was not a new concept. However, unlike the waterfall model, it is not singular. It was an ongoing growth of development ideas based on the needs of the time. Initially, Barry Boehm, James Martin, and others noticed that software was not limited by traditional engineering techniques. It was not just one resource that required a specific structure. It was flexible to meet the needs of the user (Rapid Application Development (RAD) | Definition, Steps & Full Guide, 2022).

RAD is the greatest way to quickly generate prototypes for testing software features without affecting the eventual product. Businesses prefer the RAD approach because it demands less effort in the planning phase while allowing the team to design, review, and iterate features and functionality quickly (Rapid Application Development (RAD) | Definition, Steps & Full Guide, 2022).

Requirements Planning. During this stage, the developer reached a common ground including goals and expectations during the development process. Furthermore, current and potential issues that need to be addressed during the build form part of the discussion (4 Phases of Rapid Application Development Methodology, 2018).

The researcher identified all the relevant beneficiaries, including the College Students of Divine Word College of Legazpi and its personnel. The proponent identified any project constraints, such as time, technology limitations, and boundaries of the project. After identifying the beneficiaries, the proponent gathered information by conducting interviews and surveys to understand the needs and the expectations of the beneficiaries.

Design. During this phase, to ensure that their needs are satisfied at every level of the plan preparation, clients and designers collaborate closely. It's similar to an improved customizable program where customers tried every item model at every arrangement to make sure it suited to their needs (4 Phases of Rapid Application Development Methodology, 2018).

The researcher created a prototype to visualize the user's interface and some basic functionality, develop the visual design, to perform usability testing, to identify issues, to gather feedback, to conduct testing to ensure that the prototype meets quality standards, and to continue creating and refining prototypes to visualize changes and enhancements.

Construction. The transformation of the prototype into the finished, functional product was the main focus of this phase. Since every issue and modification were handled, During the design stage, developers may work quickly to complete the application's construction here (RSK Business Solutions, 2022).

This phase included the researcher's actual coding of the prototype with continuous adjustments and refinements throughout the process.

Deployment. This last stage included the procedures for testing, switching to the new system, and converting data. This stage involved putting the application into action and launching it (RSK Business Solutions, 2022).

Final testing was undertaken by the researcher to confirm that the prototype is ready for field deployment.

Purpose, Deliverables, and Development Activities

Table 2.1

Activities of RAD Methodology

RAD Methodology	Purpose	Deliverables	Deployment Activities
Requirements Planning	Identify and define the project scope and objectives.	Project Scope document.	Identify all relevant beneficiaries and constraints.
Design	Engage end-users in the design process to gather feedback and expectations from the adviser.	User Interface Prototypes. Mock-ups and wireframes based on the adviser feedback.	Develop basic design and functional prototype.
Construction	Develop functional prototypes based on the proposed system.	Fully functional application and prototype Source code.	Actual coding based on the proposed prototype.
Deployment	Transition and development phase.	Field test.	Conduct final testing.

DATA GATHERING TECHNIQUES

A critical aspect of the system development was the collection of accurate and relevant data. This section outlined the data gathering techniques utilized to acquire the necessary information for the "DRAYB N' ARAYB" project.

It utilized online **surveys** as a primary data gathering technique. This method was used to efficiently collect the quantitative data from a broad audience. By designing a structured questionnaire distributed via email or social media platforms, a diverse group of participants was reached. Online surveys were advantageous due to their convenience and cost-effectiveness, enabling the respondents to complete their own pace. The data collected were easily analyzed using the statistical software, providing insights into trends and patterns relevant to the research objectives.

Interviews were employed in this study to gather in-depth information from the participants through direct interaction. Conducting semi-structured or unstructured interviews allowed for flexibility in questioning, which led to richer, more nuanced responses. This technique was particularly useful for exploring participants' thoughts, feelings, and experiences related to the research topic. The insights gained from interviews complemented the quantitative data from surveys, providing a more comprehensive understanding of the subject matter.

Additionally, **observation** was also incorporated as data gathering technique. This method involved watching and recording participants' behaviors and interactions in their natural settings. By employing both overt and covert observation strategies, data on personal actions and contextual factors that influenced the research topic were gathered. Observation is valuable for capturing non-verbal cues and environmental influences that surveyed and interviewed may not fully reveal. This technique enhanced the richness of the data collected, allowing for a more holistic analysis of the research questions.

SOURCES OF DATA

To ensure a data-driven approach, this section identified the sources of information employed throughout the project. A clear understanding of these data sources was essential for the success of "DRAYB N' ARAYB."

For the online **survey** technique, a diverse group of participants, drivers, including students, and administrative staff within and outside the institution were used. The survey consisted of multiple-choice and questions designed to gather quantitative and qualitative data on their experiences and perceptions related to the study topic. Questions included topics such as clients satisfaction on the current parking management in area/school grounds, regarding the difficulty of finding available parking space and the demographic information of both south and north campuses. By analyzing the responses, it aimed to identify trends and areas for enhancement based on the collected feedback from the stakeholders.

In the **interview** phase, semi-structured interviews were conducted with key individuals, including drivers, students, and DWCL personnel within the institution. During these interviews, they were asked open-ended questions to explore their insights and experiences in greater depth. For example, What are the challenges you have experienced about the school’s parking management?Do you have any suggestions to improve the school’s parking management?This approach will allow the researcher to gather qualitative data that complemented the quantitative findings of the surveys.

For the **observation** technique, it will focus on observing interactions and behaviors within specific settings, such as the parking lot within and outside the institution. It took detailed notes on how students and faculty members engaged each other and the environment. For instance, parking management was observed, including how the security personnel managed the parking lot, as well as how the DWCL personnel were prioritized entry by the school. This observational data provided context to the survey, interview and findings, revealing patterns of behavior and environmental influences that impacted the research topic.

SURVEY RESULTS

This section presented the overall 44 results obtained from a multi-method approach included in the online survey, interviews, and observations. This combined approach aimed to gain a comprehensive understanding of the user's preferences and navigation habits. The survey questionnaire focused on gathering quantitative data on the user's priorities regarding travel time, distance, traffic congestion, and parking availability. The interviews provided qualitative insights into the user's experiences and decision-making processes. Finally, observations of the user's interactions with existing systems in real-world settings was considered for a contextual understanding of the desired functionalities.

Table 2.2

Respondents Interviewed

Respondents	No. of Respondents
DWCL Students	15
DWCL Personnel	4
Total	19

As shown in table 2.2, the researcher conducted face-to-face interviews with fifteen students at DWCL to shed light on the motivations behind student parking decisions and frustrations with the current parking system. All fifteen participants unanimously cited safety as the primary reason for purchasing a car pass for the designated DWCL parking space. This finding underscored the students' significant concern about the potential for accidents when parking their vehicles on the street while attending their respective classes.

The interviews further delved into the challenges associated with the "first come, first served" policy for parking on campus grounds. Participants consistently expressed frustration with the inefficiency of queuing in the driveway without real-time information on the available parking spaces. This uncertainty often led to wasted time and ultimately resulted in students parking their vehicles behind the school grounds, exposing them to an increased risk of vehicle damage from scratches or accidents beyond their control.

These findings revealed a critical need for a more efficient and user-friendly parking solutions for the school. The current system created unnecessary stress and inconvenience for students, while failing to adequately address their safety concerns. Implementing a real-time parking information system could significantly improve the overall parking experience for the students at DWCL.

The researcher's interview of DWCL students and faculty members extended beyond students to encompass the perspectives of faculty and staff. Interviews were conducted with four DWCL personnel, providing valuable insights into the broader campus parking landscape. Similar to the students, DWCL personnel highlighted inefficiencies associated with the "first come, first served" policy. They described relying on an informal communication network through radios to check for available parking spaces within the campus grounds. This system, however, proved unreliable and time-consuming, often leading to delays and frustration. The interviews also revealed a potential issue of unequal access to parking spaces. The personnel mentioned that instructors received priority when parking inside the campus. While prioritizing faculty members' parking area is a common practice in many institutions, it's crucial to ensure a fair and transparent allocation system. Limited information for staff regarding parking availability further exacerbated this issue. These researcher's findings, combined with the concerns raised by the students, emphasize the need for comprehensive solutions to address the current parking challenges at DWCL campuses. The reliance on informal communication channels for parking information points to the limitations of the existing system. Additionally, potential inequities in parking access required careful consideration. Implementing a real-time parking information system significantly improved efficiency and fairness for all campus users. Such systems provided: Accurate information on available parking spaces and eliminating reliance on unreliable communication channels. Reduced waiting times by allowing the users to plan their arrival based on real-time data. Improved staff morale by ensuring a more transparent and equitable parking allocation system. Increased efficiency for everyone by streamlining the parking search process. By addressing the current limitations and incorporating the needs of DWCL staff, students, and faculty members, created a more efficient and user-friendly parking system for the entire campus community and arrived early in their respective classes.

Table 2.3

Respondents in the Survey

Respondents	No. of Respondents
Outsider Students	22
Employed	3
Total	25

The results of the survey presented in Table 2.3 provided compelling evidence for a strong user preference for real-time parking availability information. This finding is aligned perfectly with the themes identified in the interviews conducted in Table 2.2.

Participants consistently expressed frustration with navigating to destinations with limited parking options. They described the time-consuming and stressful experiences of "cruising" for available parking spaces near their respective campuses or companies. This combined data painted a clear picture: a critical need existed for a system that provided real-time parking data to empower the users to locate safe parking spots efficiently.

Table 2.4

Overall Number of Respondents

Respondents	No. of Respondents
Interviewed	19
Survey	25
Total	44

Table 2.4 showed that the overall respondents' parking situation is plagued by inefficiency and frustration. Finding a parking space often involved wasted time and fuel as driver's cruise for the available spots. The researcher highlighted the significant stress and wasted time associated with limited parking information. This real-time parking management system with IoT offered a powerful solution. By leveraging IoT Technology, parking sensors, and intelligent algorithms, the system provided the users with real-time parking availability and facilitated informed route planning. This translated to a more efficient parking experience for everyone, reducing wasted time,

minimizing stress, and optimizing fuel consumption. Considering both interviews and surveys, a very high percentage of participants (86.7% from interviews and 100% from those who expressed an opinion in the survey) agreed that finding a parking space is time-consuming.

Chapter 3

RESEARCH DESIGN

This chapter discussed the theorem, algorithms, mathematical tools, proposed solutions, materials and statistical tools, and the frameworks to be followed to accomplish the project.

THEOREMS, ALGORITHMS, AND MATHEMATICAL MODELS

Theorem: Nearest Neighbor Theorem

The Nearest Neighbor Theorem, also known as the Nearest Neighbor Search Theorem, is a fundamental concept in computational geometry and algorithm design. It states that in a set of points, for any point, there exists a closest point to it. In other words, given a set of points in a space with some notion of distance, there is always at least one point that is nearest to any given point (Srivastava, 2024).

Algorithm: Dijkstra's Algorithm

The goal of Dijkstra's method, a graph search technique, is to determine the shortest path (vertices) between any two nodes in a weighted graph. Envision a system of roadways (edges) linking various points (nodes), where every road has a corresponding distance (weight). This network is effectively navigated by Dijkstra's algorithm, which determines the fastest path between a starting point and a destination (Navone, 2022).

Problem Statement: To determine for a given location in a parking lot/space. The following scenarios were considered: A driver is on their way to DWCL South Campus and is faced with the frequent difficulty of locating a decent parking spot. The parking management system, equipped with IoT technology and Dijkstra's Algorithm, improved the driver's experience by providing fast access to parking availability and directing them to the parking lot of the campus. This approach is intended to speed the parking process, to minimize congestion, and to improve overall campus accessibility for both students and faculty members.

Inputs:

- User-specified origin and destination.

Output:

- The system outputs real-time parking availability.

Steps:

1. Dynamic Pathfinding with Dijkstra's:
    - Utilize Dijkstra's algorithm within a modified framework:
        - Assign edge weights in the network graph based on:
        - Static distance between locations.
    - Calculate the shortest path from origin to destination considering the adjusted edge weights.
2. User Interface:
    - Display the recommended route with corresponding real-time parking availability information.

Pseudocode:

```
# Function to find the shortest route with Dijkstra's to campus parking

1. Retrieve real-time parking availability data.

2. Adjust edge weights in the graph based on parking availability.

3. Apply Dijkstra's algorithm to find the shortest path using the adjusted weights.

4. Return the shortest path along with updated parking availability information.
```

This approach leveraged a traditional pathfinding algorithm, to offer a dynamic and user-friendly navigation experience that considered both shortest path and real-time parking availability.

PROPOSED SOLUTIONS

The researcher proposed Dijkstra's algorithm to address the limitations of current navigation systems. The system integrated real-time parking availability data to suggest efficient routes that considered both factors, will be used on parking availability and show if the parking slot/space is already occupied or not.

Dijkstra's algorithm was utilized within a modified framework. Edge weights in the network graph were assigned based on a combination of factors: the static distance between locations, dynamic adjustments based on parking availability. By dynamically adjusting these weights, the algorithm prioritized routes not only offering the shortest path but also the potential time spent searching for the available parking space.

The user interface was designed for a user-friendly experience. The system displayed the recommended route with the shortest path to the campus with parking availability information inside and outside the campus. Additionally, the users determine alternative routes with corresponding parking information. This allows them to make informed decisions based on their priorities, whether it's reaching their destination quickly or finding parking easily.

MATERIALS AND STATISTICAL TOOLS

Data were gathered through structured questionnaires and interviews and on-site observations were carried out to supplement the data gathered. Opinions from both personnel and students were incorporated in the study, to gain a more comprehensive understanding of driving experience.

Table 3.1

Materials

Type	Description	Materials
Data Sources	Sources from which data was obtained.	Interview, Survey and Observation
Data Collection Instruments	Tools/method used to collect data	Verbal Interview Google Forms Survey
Software and Technologies	Tools for data processing and analysis	C++, Arduino, Arduino IDE, JavaScript, PWA

Table 3.2

Statistical Tools

Type	Description	Materials
Descriptive Statistics	Techniques to summarize data	Mean
Data Collection Instruments	Tools for visual presentation of data	Graphs

THEORETICAL FRAMEWORK

Figure 2

Multi-Attribute Decision Making

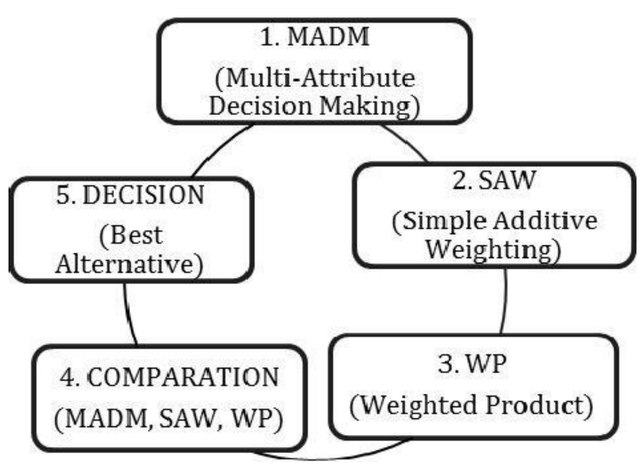


Figure 2 Multi-Criteria Decision Making (MCDM) played a crucial role in enabling user-centric route selection within our proposed dynamic navigation system. Traditional navigation systems often prioritized the shortest distance, which might not be optimal in real-world scenarios with dynamic traffic and limited parking. MCDM provided a framework to consider multiple, often conflicting, criteria like predicted travel time, distance, traffic congestion severity, and parking availability. By allowing the users to define their preferences for these criteria, the MCDM framework was ranked and suggested the most suitable route based on their individual needs. This empowered users to make informed decisions aligned with their priorities, leading to a more efficient and personalized navigation experience (Jahan et al., 2016).

Multi-Criteria Decision Making encompasses a group of methods for tackling problems where you need to choose the best option from a set of alternatives, considering multiple, often conflicting, criteria. Within the realm of Multi-Criteria Decision Making (MCDM), Multi-Attribute Decision Making (MADM) emerged as the ideal classification for your dynamic route navigation system. Traditional navigation often prioritized the shortest distance, a metric that falls short in real-world scenarios with dynamic traffic and parking limitations (Jahan et al., 2016).

MADM excels at handling problems with a finite set of alternatives and a finite number of attributes used for evaluation. This perfectly aligned with the system, where the users chose between various routes based on these multiple factors. By incorporating MADM, the system empowered the users to define their preferences for these attributes. Whether prioritizing the fastest route or finding parking quickly suggested the shortest route. This user-centric approach fostered informed decisions aligned with individual travel needs, leading to a more efficient and personalized navigation experience. By incorporating MADM, the system empowered the users to make informed decisions based on their individual needs. The users prioritized the travel time, finding parking, or a balance between both.

MADM provided a robust framework for the dynamic route navigation system. It catered to the specific requirements of the project by focusing on a finite set of alternative routes and allowing the users to define their preferences for the multiple attributes that influence their travel decisions.

CONCEPTUAL FRAMEWORK

Figure 3

Conceptual Framework of the System

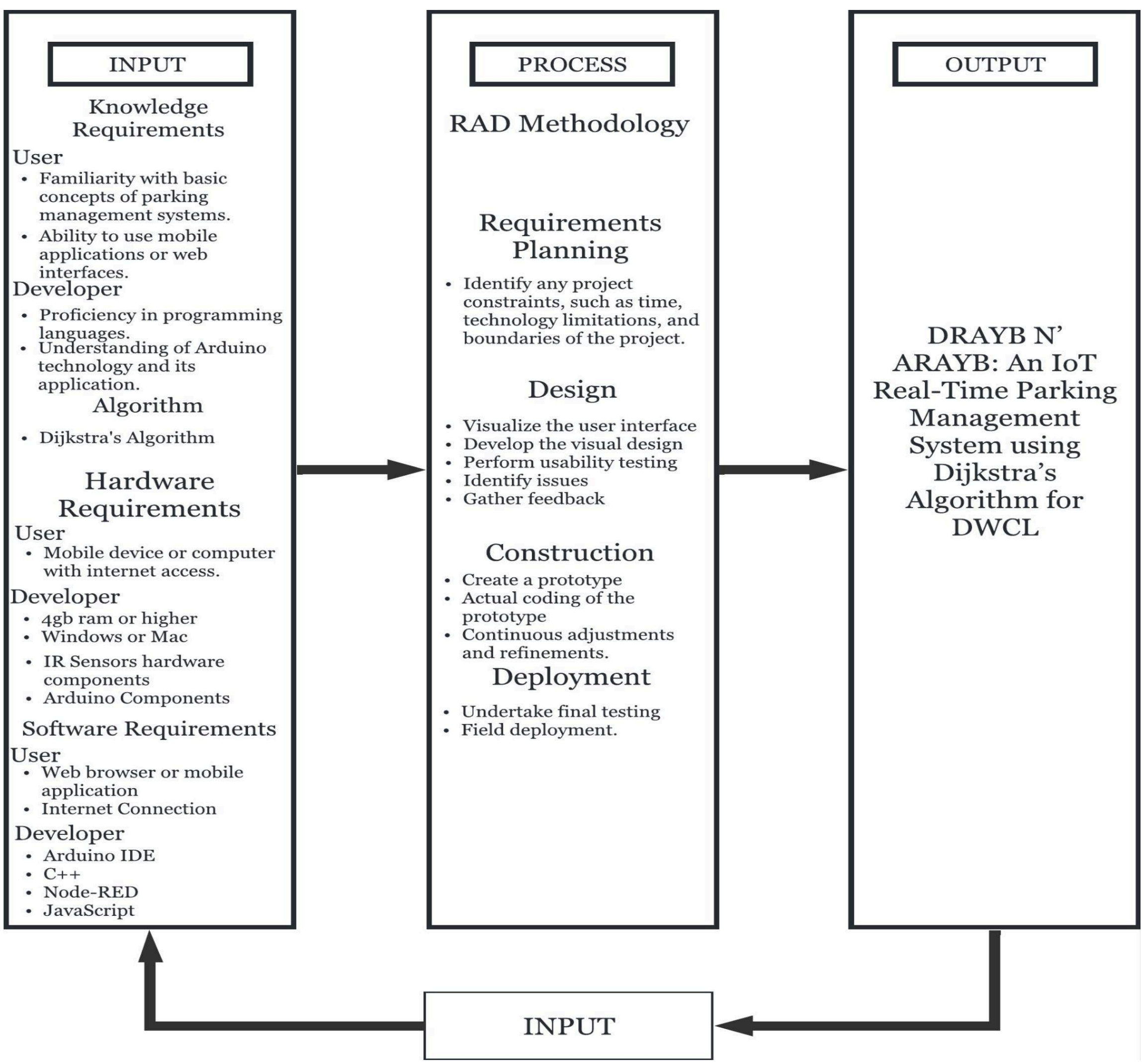


Figure 3 showed the input, process, and output of the proposed system where the input is represented by knowledge requirements wherein the user and the developer possessed certain knowledge and qualifications to develop the system. For the Web App to be operated, the user must know how to operate it and have experienced using a Web Browser while the developer met the needs by having skills in software development, knowledge in IoT, Arduino, and software development methodologies. For the user to use the system, a mobile phone is required for the web application where they could access the web app. On the other hand, the developer performed the development of the system through a desktop computer or a laptop which possessed a sufficient amount of storage and was connected to a stable internet connection.

Chapter 4

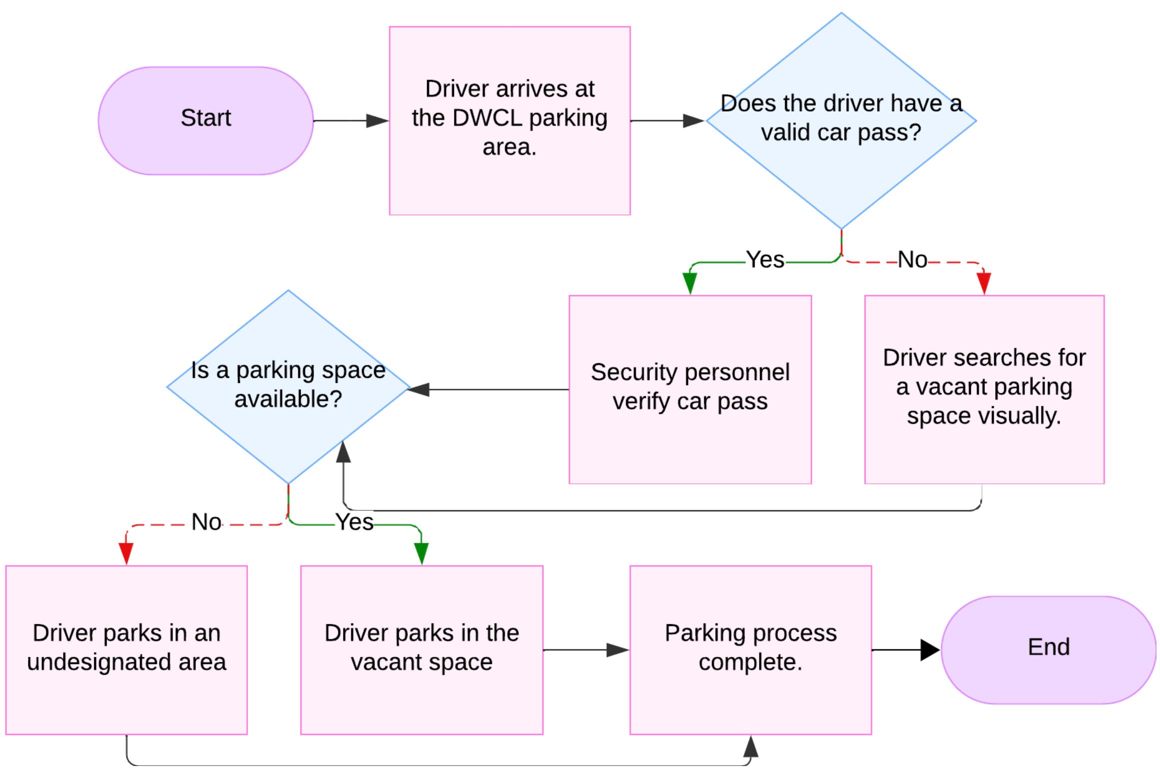
REQUIREMENT ANALYSIS AND DOCUMENTATION

The requirements, analysis and documentation were presented in the figures of the chart, system architecture, software design, namely, the use case, class, and sequence diagrams. It also included tables for database design, system requirements, system tradeoffs, system design, project timeline, and statistical tools.

FLOWCHART

Figure 4

FlowChart on the Manual Process of Parking

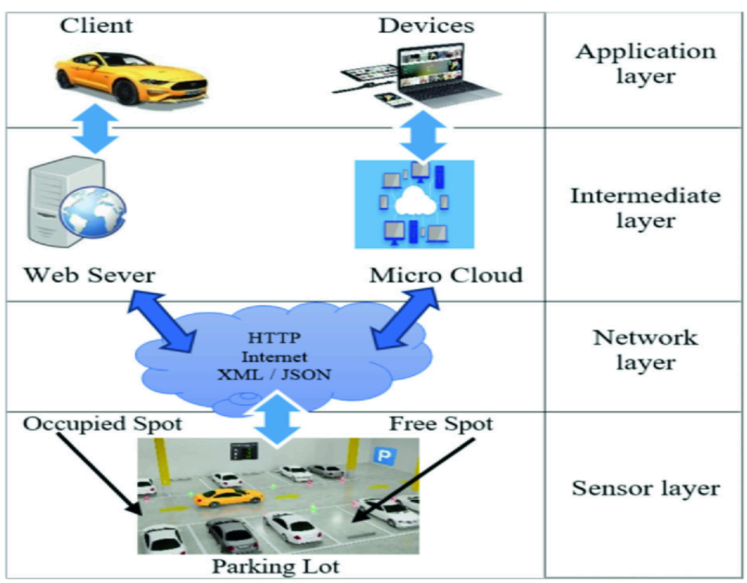


In figure 4, The manual parking process is a streamlined approach to vehicle parking that eliminates the need for complex ticketing or payment systems, making it an efficient option for free or private parking facilities. This process begins with the entry of the vehicle into the parking area, followed by the driver navigating to and parking in an available space. Once parked, the driver notes the location of the parking spot for future reference. The process concludes with the vehicle exiting through a designated gate, often facilitated by minimal security or automated systems. This simple and user-friendly system prioritizes convenience and accessibility, making it suitable for environments where operational efficiency is key.

SYSTEM ARCHITECTURE

Figure 5

System Architecture



In figure 5, it showed the system architecture laid out a flexible approach to parking management at DWCL, accommodating both a potential future automated system and the current manual process. For an automated system, Arduino and sensors captured real-time data, feeding into a central processing unit for analysis and parking availability conditions. A user interface via app displayed this information for parking availability.

SOFTWARE DESIGN

The following sections delved into the intricate design of the "DRAYB N' ARAYB" prototype. This comprehensive overview provided a clear understanding of the system's architecture, functionalities, and technical intricacies.

Use Case Diagram

Figure 6

Use Diagram of the System

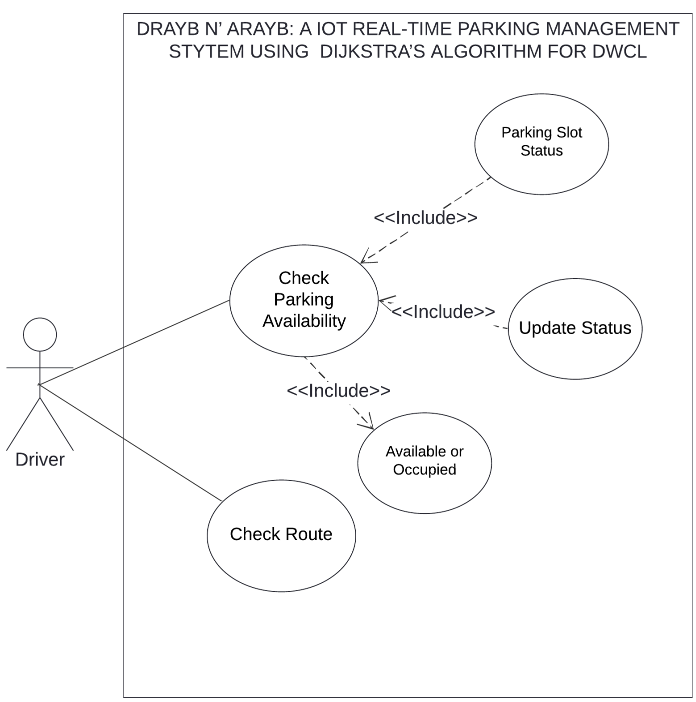
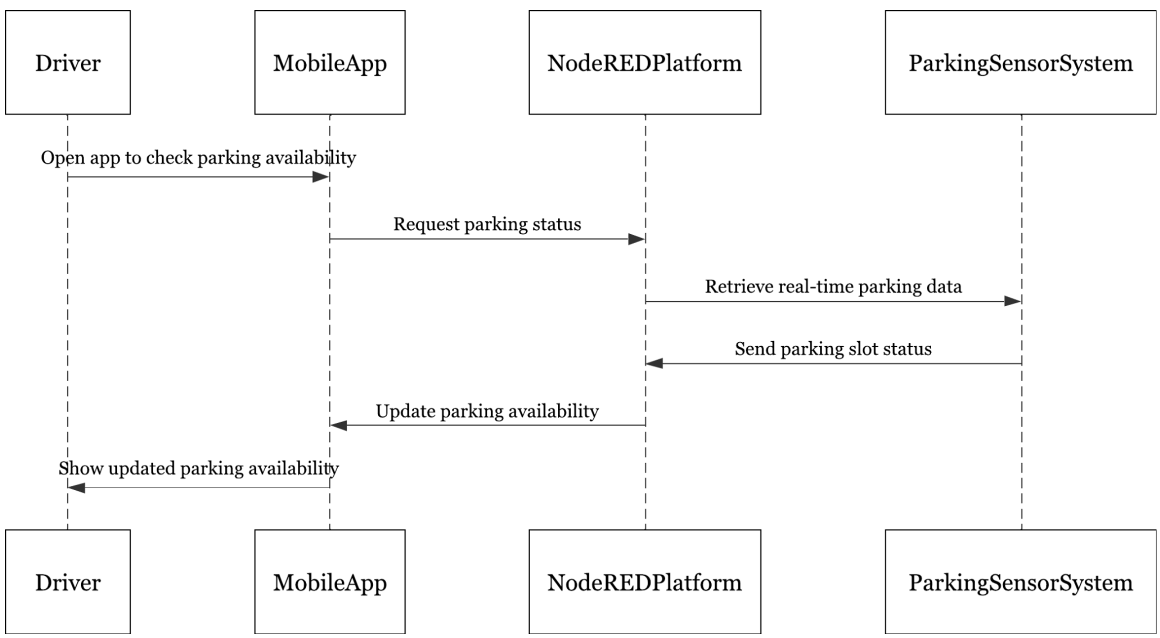


Figure 6 showed a parking management system using IoT Device to monitor parking slot availability in real time. The Driver checked parking status via a mobile app using the Node-RED platform. IR sensors detected whether parking slots are occupied or still available and sent updates to the Node-RED web app. The app then provided real-time parking availability to the driver's phone, allowing them to find parking quickly and efficiently. This system streamlined parking by continuously monitoring and updating slot statuses.

Sequence Diagram

Figure 7

Sequence Diagram of the System



In figure 7, it showed the sequence diagram for the parking system prototype that depicted the message flow between system components during specific scenarios. For example, it could illustrate the interaction when a vehicle entered the lot: the Arduino sent the signal to the CPU, checked for available spaces, and finally sent a signal to the app. This visual representation helped understand the precise sequence of messages exchanged between components during key interactions within your parking management system.

Class Diagram

Figure 8

Class Diagram of the System

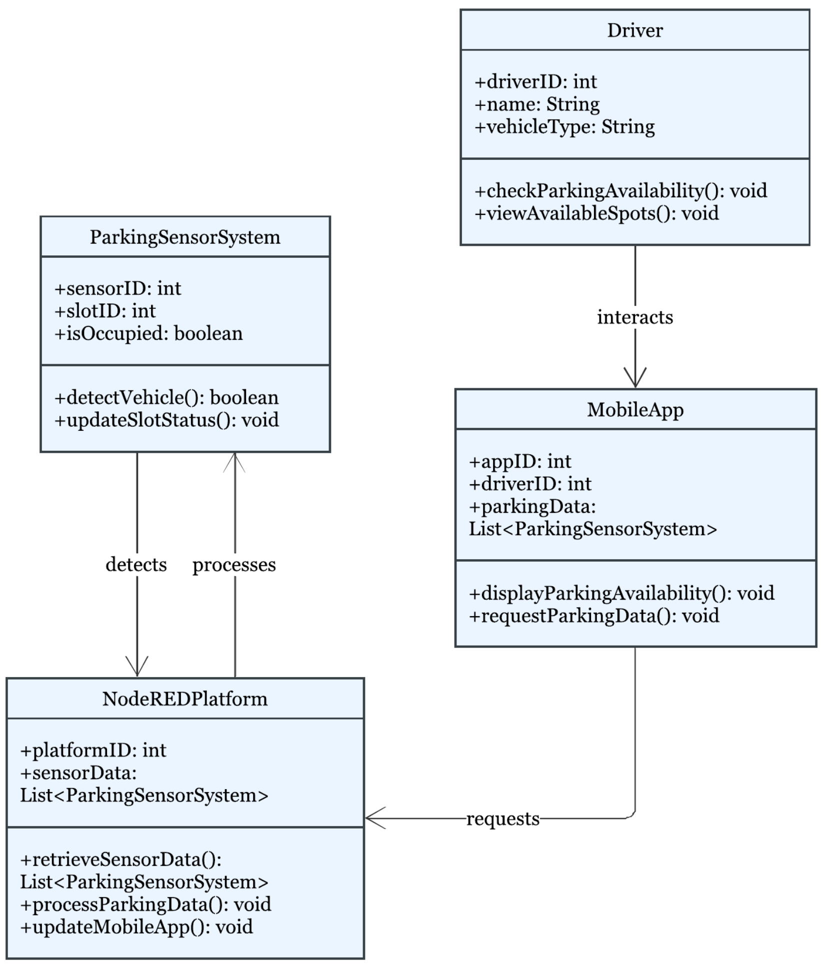


Figure 8 discussed the Class diagram of the Proposed System. The main features of the DRAYB N' ARAYB system are shown in the class diagram. It contained necessary classes (MobileApp, ParkingManagementSystem, SecuritySystem), actors (Driver and Personnel), and the CarPass class for access control. To collect data, the Arduino and MobileApp communicated. The user is presented with features like navigation (optional; future development) and real-time availability. The system is managed by the ParkingManagementSystem, which communicates with Parking Spaces, the SecuritySystem, and the optional, future-developed SensorNetwork for future sensor data integration. ParkingSpace features include ID, location, and status (occupied/vacant). You can also choose which sorts of car passes are authorized.

SYSTEM REQUIREMENTS

For further understanding the thesis aimed to explore the intricacies of the system requirements, focusing on both functional and non-functional aspects. Functional requirements detailed the specific capabilities and behaviors that the system must exhibit, while non-functional requirements addressed performance metrics, usability standards, security considerations, and other quality attributes essential for user satisfaction.

By systematically analyzing and documenting these requirements, this research sought to establish a comprehensive framework that guided the development process, mitigates risks, and enhanced the overall effectiveness of the system. The findings contributed to a deeper understanding of how well-defined system requirements lead to successful software implementations, ultimately benefiting stakeholders and end-users alike.

Hardware Requirements

This section outlined the hardware needed to run Server effectively. In this part, the minimum and recommended specifications to ensure a smooth user experience were discussed.

Table 4.1

Recommended Server Hardware Specifications

Required Hardware	Specifications
Server	
OS	Linux()
CPU	Intel i5 11th Gen
DISK	500GB SSD
Transfer	100 Mbps

Table 4.2

Recommend Client Hardware Specifications for Phone

Required Hardware	Specifications
Client	
Processor	Android 5.1 and up, and on iOS 9.0 or later.
Memory	4GB ram or higher
Internet Bandwidth	30 Mbps
Devices	Phone

Table 4.3

Recommend Researcher Hardware Specifications for PC

Required Hardware	Specifications
Client	
Processor	Windows 10 or higher or MacOs Sonoma or higher
Solid State Drive	128GB SSD or higher

Memory	4GB ram or higher
Internet Bandwidth	30 Mbps
Devices	Laptop/PC

Table 4.4

Prototype Hardware Requirements

Hardware	Specifications
Microcontroller	ESP32 (or equivalent)
Power Supply	USB cable or Battery Pack
Sensors	Ultrasonic Sensor or Infrared Sensor
Breadboard	Standard half-size or full-size breadboard
Jumper Wires	Male-to-male or female-to-female wires

Software Requirements

This section detailed the software required to run effectively. The outline in operating the system versions and any additional software dependencies needed for proper functionality is discussed.

Table 4.5

Recommend Software Specifications

Particulars	Specifications
Language	C++ and JavaScript
Framework	Node-RED
Database	

SYSTEM TRADEOFFS

System trade offs included various challenges in designing both software and hardware elements. This principle was all about developing fundamental trade-offs of the design. The main factors for discussion were techno-economic and operation-related matters.

Table 4.6

Technical Issues

Technical Issues	Tradeoffs
Performance	The Desktop/Laptop must possess at least 2.3 GHz
Deployment	Windows 10 or higher
Operational Characteristics	To develop in desktop/laptop with at least 8GB RAM
Interoperability with other Technologies	Can be developed with Progressive Web Apps.

Table 4.7

Operational Issues

Operational Tools	Tradeoffs
Support Tools	Scribbr, Quillbot, Google Scholar
User and Developer Skills	Uses JavaScript and C++ in coding. The developer should have at least a knowledge about IoT technology and Arduino.
Processes	Each stage has a challenge and used Dijkstra's Algorithm, steering and path following algorithm that applied to the Prototype.
Documentation	Research about the IoT Technology, DWCL Parking Situation

Table 4.8

Economic Issues

Economic Issues	Tradeoffs
Hardware and Software Updates	This application will work well if the RAM(Memory) is higher.
Development Cost	The estimated development cost for this study would be: Php 10,000.00 Breakdown: ● Hardware :Php 3,000.00 ● Development fee :Php 3,000.00 ● Service fee :Php 2,000.00 ● Miscellaneous :Php 2,000.00
Operational Cost	The estimated operational cost for this study would be: Php 21,000.00 Breakdown: ● Electric Bill : Php 2,000.00 ● Transportation : Php 2,000.00 ● Internet : Php 6,000.00 ● Survey Expenses : Php 1,000.00 ● Food : Php 2,000.00
Training Cost (Developers and Users)	Overall Training Cost: Php 3,000.00 Breakdown: ● Service fee : Php 1,000.00 ● Transportation : Php 1000.00 ● User's Manual : Php 500.00 ● Food : Php 500.00

SYSTEM DESIGN

The real-time parking management system designed for DWCL can be manual or automated. The manual system prioritized lower initial cost with designated parking zones and a formal communication channel for real-time updates. An automated system, while requiring a higher initial investment, offered greater efficiency and scalability through parking sensors, algorithms for availability, and user interfaces for real-time information and navigation. The optimal design is dependent upon the DWCL's budget, desired automation level, and security considerations.

Table 4.9

Non-Functional Requirements

	Properties	Constraints
System	Availability Reliability Security Scalability	99% uptime during operational hours < 0.1% data loss rate
Software	Maintainability Performance Accessibility	Modular design for easy updates and bug fixes Software User-friendly interface with clear instructions Software Response time < 2 seconds for most operations
User	Usability	Can be access by all
Service	Cost-effectiveness Sustainability Interoperability	Affordable maintenance and operation costs Energy-efficient hardware and software Integration with existing campus systems

Table 4.9 provided examples of common non-functional requirements for a parking management system. The specific requirements for your project may vary.

Table 4.10

Functional Requirements

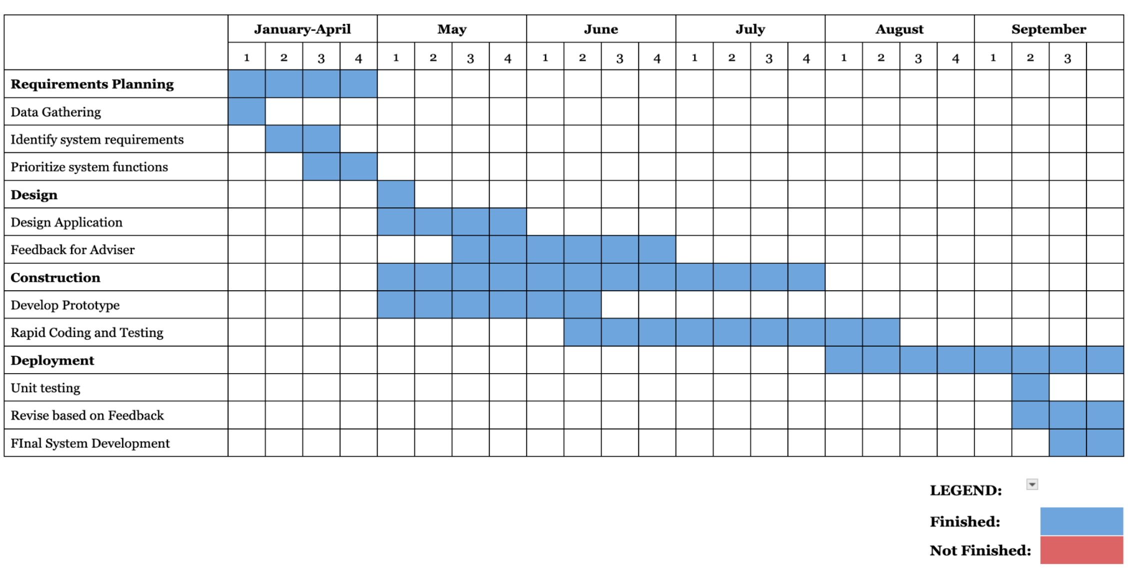
Input	Process	Output	Storage	Control
Infrared Sensor	Detects Availability	Availability	Stores data if the parking is available	Server side controls
Parking sensor data	Determine parking space occupancy	Update real-time parking availability information	Parking space status (occupied/vacant)	Parking zone configurations (e.g., number of spaces, disabled parking, optional)
User request for parking information (mobile app)	Display available parking spaces and directions (optional)	Real-time parking availability	Realtime data	User interface settings (e.g., language, preferences) Optional

The table 4.10 provided examples of common functional requirements for a real-time parking management system. The specific requirements for the project varied based on the chosen functionalities and system design.

PROJECT TIMELINE

Table 4.11

Gantt Chart



The table 4.11 outlined key phases like Requirements Planning, User Design, Construction, and Implementation, to ensure that the project stayed on schedule by visualizing deadlines and dependencies between tasks.

Chapter 5

FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This chapter presented the researchers findings, conclusions, and recommendations.

FINDINGS

This study investigated key challenges encountered by the drivers in the Divine Word College of Legazpi (DWCL) parking area, focusing on three primary issues: real-time parking availability, optimal routing to available spaces, and effective parking management.

1. Problems Encountered by Drivers:
   a. Locating Available Parking Spaces: Drivers frequently struggled to find open parking spots due to a lack of real-time availability information. This difficulty increased frustration, prolonged search times, and contributed to traffic congestion.
   b. Efficient Routing to Parking Spaces: Without a guided system for directing drivers to the nearest available spaces, routing becomes inefficient, leading to delays, vehicle idling, and added emissions.
   c. Parking Management Limitations: Current parking management practices lack a centralized monitoring system, which lead to inefficient space utilization and challenges in enforcing parking regulations.
2. Algorithm for Pathfinding:
   a. Pathfinding: Dijkstra’s Algorithm is for optimizing the path to the nearest parking space. This algorithm calculated the shortest path in a weighted graph, ensuring that drivers are directed to the available parking spots in the most efficient manner.

3. Features of the System, "DRAYB N' ARAYB":
   a. Real-Time Parking Availability: The system provided real-time updates on parking space availability, allowing the drivers to make informed decisions before arriving at the parking area.
   b. Path Optimization: Utilizing Dijkstra's Algorithm, the system offered optimized routing to the shortest path to the parking area, reducing search time and improving overall traffic flow.
   c. User-Friendly Interface: The system featured an intuitive interface allowing the users to easily access parking information and navigation assistance.
4. Using the software quality model - ISO 25010 evaluation tool:
   a. The IT experts evaluated the proposed system ratings: Compatibility (4.00), Reliability (3.67), Usability(3.87), and Maintainability (3.73) and the overall rating in (3.82) it was (More than What is Expected).
   b. The User's Evaluation also obtained with the weighted scores of: Compatibility (3.70), Reliability (4.40), Usability(4.53), and Maintainability (4.00) and the overall rating is (4.16) and it was (More than What is Expected).

CONCLUSIONS

Based on the findings, the conclusions below were derived:

1. The primary challenges faced by drivers in the parking area of Divine Word College of Legazpi (DWCL) include congestion, difficulty in locating available parking, and parking management inefficiencies. Congestion arises from inefficient routing and

prolonged searches for open spaces, leading to driver frustration and campus-wide traffic buildup.Locating Available Parking is further complicated by the absence of real-time parking availability information, resulting in extended search times, increased vehicle idling, and heightened driver dissatisfaction. Additionally, Parking Management suffers due to the lack of a centralized system for monitoring space utilization and enforcing regulations, causing underutilized spaces, inconsistent rule enforcement, and overall inefficiencies in meeting campus parking demands.

2. "DRAYB N' ARAYB," addressed the issues above to make the parking and route easier for the drivers. They were provided with real-time parking availability information and optimized shortest routes to campus using Dijkstra's Algorithm. This system directly mitigated the issues of congestion, inefficient routing, and parking space underutilization, resulting in a more streamlined and effective parking process.

3. The evaluation of the system using the ISO 25010 quality model further validated its effectiveness. IT experts gave favorable scores across multiple metrics, with an overall rating of 3.82, surpassing expectations. The user evaluation echoed these findings, with higher scores in categories like usability and reliability, leading to an overall user rating of 4.16. These positive evaluations demonstrated that the proposed system not only met but exceeded the user's expectations in providing a practical solution to parking challenges at DWCL.

4. Overall, this study highlighted the potential of technology-driven solutions to improve parking management, to reduce congestion, and to enhance user experience in educational institutions and similar environments. The successful application of Dijkstra's Algorithm for path optimization and the positive feedback from both experts and users suggested that this system served as a model for addressing parking challenges in other settings as well.

RECOMMENDATIONS

Based on the conclusions, the following recommendations were formulated.

1. Enhance its functionality, consider adding a camera for visual feedback, and a small display on the Arduino for basic information.

2. On the software side, integrate real-time video streaming, traffic monitoring, and compatibility with other systems.

3. Explore machine learning for data analysis and prediction. For a better user experience, design an intuitive web app interface, implement push notifications, and enable social sharing.

4. Consider not limiting the study inside the institution, which could further illuminate the complexities surrounding 'Drayb n' Arayb.' This thesis underscored the importance of IoT devices in today's ever advancing technologies, highlighting the need for continued exploration in this vital area of study.

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Appendix A

LETTER

February 6, 2024

Dear Sir/Madam,

Good Day, I am Rey Gabriel L. Literal, a 3rd Year Bachelor of Science in Computer Science Student at Divine Word College in Legazpi. Currently, I am enrolled in Thesis Writing 1, and my proposed study is titled "Drayb n' Arayb: An Iot Real-Time Parking Management Systems using Dijkstra's Algorithm for Divine Word College of Legazpi" The system aims to provide real-time information about available parking spots using Iot technology.

In connection with this, I would like to ask permission to allow me to conduct an interview in order to gather insight and information regarding individuals' driving experiences when locating parking spaces in private, public, and commercial parking lots. The purpose of this interview is to gain a deeper understanding of the technical aspects, operational challenges, and potential benefits associated with Parking in Public, Private and Commercial Spaces. Your participation in this interview would be greatly appreciated as it would contribute significantly to the success of my thesis and the advancement of knowledge in this field.

The data collected will be used solely for the purpose of my thesis study, and I assure you all the information will be treated with utmost confidentiality.

Yours sincerely,

(Sgd.)**REY GABRIEL L. LITERAL**
Researcher

Noted by:

(Sgd.)**REILAN L. CADUBLA**
Thesis Adviser

Appendix B

QUESTIONNAIRE

Note: The data collected will be used solely for the purpose of my thesis study, and I assure you all the information will be treated with utmost confidentiality.

1) How often do you struggle about finding a parking space?
2) What are your methods of find parking?
3) How important to you to find parking quickly?
4) How hard is finding a parking space in your area?
5) What are some challenges of parking management inside the institution?
6) Is there a time that you/they queued for parking and not getting a spot?
7) What challenges do you face when trying to find parking?
8) Is real-time parking availability help you with this challenges?
9) In your opinion, do you think the system can help you easily find parking? In what way?

Appendix C

SOURCE CODE

DIJKSTRA'S ALGORITHM

Dijkstra's algorithm is used to find the shortest path between two nodes in a weighted graph.

1. Constructor

```
constructor() {
   super();
   this.openList = [];
}
// The constructor initializes the openList (priority queue) as an empty array.
```

2. Start Method

```
start(startNode, endNode) {
   super.start(startNode, endNode);
   this.openList = [startNode];
}
//This method calls the parent class's start method and then adds the start node to the
openList.
```

3. NextStep Method

```
//This is where the core logic of Dijkstra's algorithm resides:
nextStep() {
       if (this.openList.length === 0) {
          this.finished = true;
          return [];
       }

       const updatedNodes = [];
       const currentNode = this.openList.shift();
       currentNode.visited = true;
       const refEdge = currentNode.edges.find(e => e.getOtherNode(currentNode) ===
currentNode.referer);
       if(refEdge) refEdge.visited = true;

       // Found end node
       if (currentNode.id === this.endNode.id) {
          this.openList = [];
```

```
      this.finished = true;
      return [currentNode];
    }

    for (const n of currentNode.neighbors) {
      const neighbor = n.node;
      const edge = n.edge;

      // Fill edges that are not marked on the map
      if(neighbor.visited && !edge.visited) {
        edge.visited = true;
        neighbor.referer = currentNode;
        updatedNodes.push(neighbor);
      }

      if (neighbor.visited) continue;

      const neighborCurrentCost = currentNode.distanceFromStart + edge.weight;

      if (this.openList.includes(neighbor)) {
        if (neighborCurrentCost >= neighbor.distanceFromStart) {
          continue;
        }
      }
      else {
        this.openList.push(neighbor);
      }

      neighbor.distanceFromStart = neighborCurrentCost;
      neighbor.parent = currentNode;
      neighbor.referer = currentNode;
    }

    return [...updatedNodes, currentNode];
  }
```

Appendix D

PILOT TESTING RESULTS

IT Professionals

IT Experts Evaluation										
			n =	3						
		Indicators	Frequency						Weighted Mean	Adjectival Description
			5	4	3	2	1	Total		
Characteristic	Sub-Characteristic	Key Areas (Indicators)								
1. **Compatibility** *is the capability system can exchange information with other products, systems or components, and/or perform its required functions while sharing the same hardware or software environment*										
	Co-Existence	The system can perform its required functions efficiently while sharing a common environment and resources with other products, without detrimental impact on any other product.	1	1	1	0	0	3	4.00	More Than What is Expected
	Interoperability	The system can exchange information and use the information that has been exchanged.	1	1	1	0	0	3	4.00	More Than What is Expected
	Sub-Average (3)								4.00	**More Than What is Expected**
2. **Usability** *is the ability of the system can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.*										
	Appropriateness recognizability	Degree to which users can recognize whether a product or system is appropriate for their needs.	1	1	1	0	0	3	4.00	More Than What is Expected
	Learnability	The system can be used by specified users to achieve specified goals of learning to use the product or system with effectiveness, efficiency, freedom from risk and satisfaction in a specified context of use.	1	1	1	0	0	3	4.00	More Than What is Expected
	Operability	The system has attributes that make it easy to operate and control.	1	1	1	0	0	3	4.00	More Than What is Expected
	User interface aesthetics	Degree to which a user interface enables pleasing and satisfying interaction for the user.	0	1	2	0	0	3	3.33	Presence of the Expectation
	Accessibility	The system can be used by people with the widest range of characteristics and capabilities to achieve a specified goal in a specified context of use.	1	1	1	0	0	3	4.00	More Than What is Expected
	Sub-Average (4)								3.87	**More Than What is Expected**
3. **Reliability** *is the capability of the system or component performs specified functions under specified conditions for a specified period of time.*										
	Maturity	The system is ready to handle and manage records/data of Aemilianum College Inc.	1	0	2	0	0	3	3.67	More Than What is Expected
	Availability	Degree to which a system, product or component is operational and accessible when required for use	1	0	2	0	0	3	3.67	More Than What is Expected
	Sub-Average (5)								3.67	**More Than What is Expected**
4. **Maintainability** *is the capability of the system can be modified to improve it, correct it or adapt it to changes in environment, and in requirements.*										
	Modularity	The system program is composed of discrete components such that a change to one component has minimal impact on other components.	1	0	2	0	0	3	3.67	More Than What is Expected
	Reusability	Degree to which an asset can be used in more than one system, or in building other assets.	1	0	2	0	0	3	3.67	More Than What is Expected
	Analyzability	Degree of effectiveness and efficiency with which it is possible to assess the impact on a product or system of an intended change to one or more of its parts, or to diagnose a product for deficiencies or causes of failures, or to identify parts to be modified.	1	1	1	0	0	3	4.00	More Than What is Expected
	Modifiability	Degree to which a product or system can be effectively and efficiently modified without introducing defects or degrading existing product quality.	0	2	1	0	0	3	3.67	More Than What is Expected
	Testability	Degree of effectiveness and efficiency with which test criteria can be established for a system, product or component and tests can be performed to determine whether those criteria have been met.	0	2	1	0	0	3	3.67	More Than What is Expected
	Sub-Average (7)								3.73	**More Than What is Expected**
	Over-All Average								3.82	**More Than What is Expected**

End User

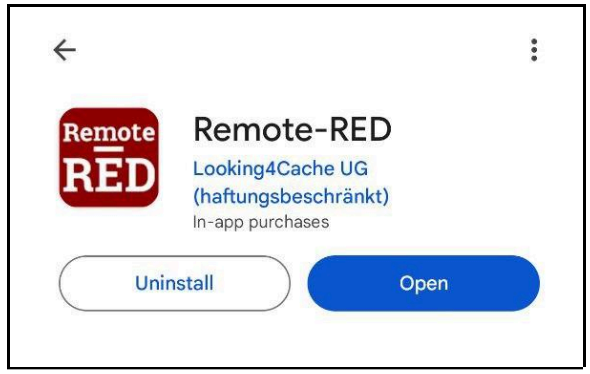
Characteristics	Indicators	Frequency 5	4	3	2	1	Total	Weighted Mean	Adjectival Description
1. Reliability	The system is ready to process data.	2	3	0	0	0	5	**4.40**	More Than What is Expected
2. Usability	The system is user-friendly.	4	0	1	0	0	5	4.60	Far More Than What is
	The system has functions and features that can be easily learned by the user.	3	1	1	0	0	5	4.50	More Than What is Expected
	The system has the interface and functions that can be operated by user.	1	3	1	0	0	5	4.50	More Than What is Expected
	The system's design and interface are visually and user-friendly attractive.	2	1	0	2	0	5	4.50	More Than What is Expected
Sub-Average (3)								**4.53**	Far More Than What is Expected
3. Maintainability	The system's performance can be straightforwardly gauge in a run-through test to find out how its features work.	2	1	2	0	0	5	**4.00**	More Than What is Expected
4. Compatibility	The system can perform its required functions efficiently while sharing a common environment and resources with	0	4	1	0	0	5	3.80	More Than What is Expected
	The system can exchange information and use the information that has been exchanged.	0	3	2	0	0	5	3.60	More Than What is Expected
Sub-Averag(8)								**3.70**	More Than What is Expected
	Over-All Average							**4.16**	More Than What is Expected

Appendix E

USER'S MANUAL

Step 1

Download the ***Remote-Red APP*** and Open it.

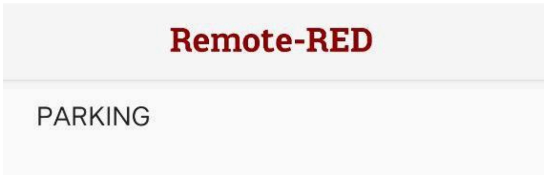


Step 2

Click the ***ADD NODE-RED INSTANCE*** at the bottom of the app to Scan the QR Code Given.

Step 3

Scan QR CODE
(Note: Example Only)

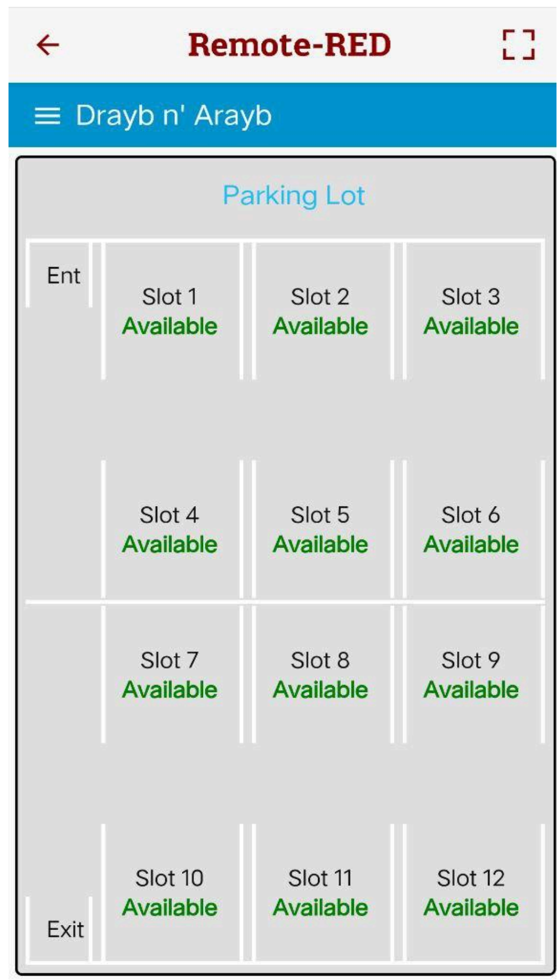


Step 4

After scanning you will see the "PARKING" to open the Parking Lot

Step 5

You can now see if the Parking Slot is Available or Occupied



CURRICULUM VITAE

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PERSONAL INFORMATION:

Birthdate	: July 19, 2002
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EDUCATIONAL ATTAINMENT:

Tertiary	: Divine Word College of Legazpi Course: BS Computer Science
Secondary	: Marcial O. Rañola Memorial School Year Graduated: 2020
Elementary	: Camalig North Central School Year Graduated: 2015