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IoT-Based Smart Parking Management System

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Abstract:- The study utilized IoT technology to improve parking efficiency and user convenience. The system contained a device that can accurately detect the status of parking slots. This includes when a slot is occupied, vacant, or reserved. When an unauthorized vehicle occupies a reserved slot, the equipped alarm system is triggered. The system also features a mobile application that provides real-time information on nearby parking lots and their status. The application included reservation and navigation features, supports secure payment options, and incorporates a smart redirection feature to guide users to alternative parking lots when their chosen option is full. The hardware device achieved 100% accuracy in slot status detection. In all the trials conducted, the alarm system succeeded in alerting unauthorized vehicles. The smart redirection feature successfully navigated users to nearby available parking lots when their initial choice was full. The findings demonstrate the system's working functionality. The system passed in the conducted tests suggesting that it can improve driver experience when looking for parking.

Keywords:- *IoT Technology, Real-Time Information, Smart Redirection, Reservation, Mobile Application.*

I. INTRODUCTION

WITH the continuous innovation of technology, using automobiles as a mode of transportation became necessary as it provided people with a sense of independence and freedom of mobility. As a result, the rapid increase in car ownership caused a shortage of open parking areas worldwide. A better parking management system to oversee this rapid increase is needed. According to the Census and Economic Information Center (CEIC, 2021) records, the number of cars has been increasing steeply over the past decade, while parking spaces have yet to meet the demand of most big urban cities. The Philippines' number of registered vehicles data is updated yearly, and according to the data, an average of 2,577,529 units from December 1981 to 2021 are being produced annually. The data also reached an all-time high of 4,591,662 units in 2021. Illegally parked cars have also been a massive headache for people and have been causing traffic to be more congested. An article by Tiangco [1] (2020) shows that the Manila city government clamped 827 cars and 33 motorcycles in its large-scale clearing and clamping operations on a specific date. This shows the severity of the illegal parking issue in this country, and it needs to be fixed. Another article from Garcia [2] (2017) states that 38% of the respondents that have been interviewed about car parking experience noted that the waiting time for looking for parking is 5 to 10 minutes, and 37% of the respondents claimed that an average of 20 minutes is being spent in finding or waiting parking slots to clear up. Considering this, an IoT Based Smart Parking Management System was conceived.

According to a study by Parmar et al. [3] (2020), psychological and parking characteristics play essential roles in parking choices. A Parking policy should be integrated with transport planning for sustainable growth, and parking should be part of urban city planning. This is because the demand for parking spaces is steadily increasing and will provide economic and environmental benefits. A study by Mushtaq et al. [4] (2020) has brought reference to how the overview of the system works. The proprietors have used sensory circuits like RFID to detect and verify the vehicle owner's information, like car model, year, registration, registered owner, and if the specific party has reserved a parking space. IoT also accessed and loaded the generated data to the cloud remotely. This was done in a closed setting. The RFID tag is an excellent device for verifying the owner's information. However, in this research, it was decided by the proponents that the user's data would be collected through the app. IoT was also a good use as it will be great to collect data and access the system remotely compared to manually collecting data. A study by Agarwal et al. [5] (2021) integrated using E-payment methods in their work. The study has designed an app to aid in the management of the parking area. The researchers also used RFID sensors to verify the car owner's details. IR sensors detected whether the parking spot was vacant or occupied. The E- payment system has been integrated into the app for easy payment and parking convenience. The study by Chandran [6] (2019) has a similar approach to the previous research. IR sensors were also used, but Arduino Raspberry Pi has been the primary system. Communication modules have also been used in this study to keep track of the system's activity. A mobile application was also designed. This is where the communication modules send the data to have an update on the status of the systems. The study by Khanna et al. [7] (2016) used different devices; Passive IR Sensors (PIR) and ultrasonic sensors have been implemented to detect whether the parking space is vacant or occupied. The system also has a confirmation feature of whether the booked vehicle is in the correct spot. It will be displayed when the car has been parked correctly. According to Parmar et al. [3] (2020), the gaps the researchers encountered are that it only analyzes the demand for parking. Despite administering a survey for different factors that private vehicle owners prefer, it did not make any correlation. It showed some sample solutions, but another author references them. The study is only a simple overview of parking in urban areas. In the Reservation-based smart parking system by Wang [12] (2011), the study focused solely on automation and reservation. The study has many gaps, such as invasive data collection, and it requires web servers and portals, which is not applicable in the Philippines. Annand's IoT-based smart parking system [7] (2016) has problems in the payment system as it can only be done electronically. The data is unreliable since it is only done in a closed setting. Another IoT-based smart parking system conducted by Agarwal et al. [5] (2021) also faced similar problems wherein the e-payment system is problematic since there is no reliable connectivity and the lack of proper IT infrastructures in cities. The app and system require a significant learning curve for the citizens to utilize the app. It also has concerns about security and updates.

This study aims to design and develop an IoT-based smart parking management system. Specifically: (1) To develop a device using ultrasonic sensors that detect the status of a parking slot, (2) To develop an application that displays the information on parking lots and enables remote reservation, (3) To integrate a smart feature that allows for redirection when a parking lot is full.

This study is essential to students, employees, and tourists traveling by private vehicle to Intramuros because it provides an application to help people quickly locate available parking spaces. It will provide an application that can help optimize parking in Intramuros and help minimize illegal parking. It helps in being able to reserve a parking space to ensure that users will have one. It will also confirm the parking spaces that are legal and give a sense of security to users of the application.

The study focused on and covered only the coding, development, and testing of a smart parking management system. The prototype has been tested through two (2) private parking lots inside the walls of Intramuros, Manila. The remaining parking lots will be tested through a simulation. The parking options present in the system only include those that are private parking areas. The study does not expand on the exploration of an intrinsic alarm system. Testing for the optimal power source for the prototype is also not included in the scope of the study. This study did not include or cover the device's durability.

II. REVIEW OF RELATED LITERATURES

A. Software Quality Assurance

A study by Ajchariyavanich T. et al. [8] (2019) entitled “Park King: IoT-based Smart Parking System.” The study has set criteria for the effectiveness of the prototype. They have used a Software Quality Assurance (SQA) Test to justify the requirements that have been defined.

B. Parking Behavior

On Parking Behavior reference, a survey conducted by McGuckin and Murakami [9] (2002) found that the duration a driver spends in a parked vehicle before exiting varies from 10 seconds to over 10 minutes. The research surveyed men's and women's habits in a parking lot in a shopping mall. Respondents ranged from single men/women to those who had families. However, from all the collected data, the average time drivers spend in their parked vehicles is 36 seconds. It also showed that women spend more time in their parked cars before exiting them. A similar study regarding Parking Behavior was conducted by Oyama and Fujii [13] (2013) titled "An observational study on the characteristics of parked cars in a residential area," where it expounds parking behavior by looking into the time drivers spend in parked vehicles in a residential area. The study used the mean of the duration of the stay. The study found that the duration was between 14 seconds to 6 minutes and 20 seconds. This, however, is also influenced by factors such as the driver's age, the presence of passengers, and the time of day. The average time is 1 minute and 20 seconds. On the other hand, a study by Strathman and Harker [10] (2005) entitled "The relationship between parking location and the time that drivers spend in their parked vehicles" also discusses parking behavior. The study concluded that drivers spend 10 to 125 seconds in their vehicles. The median time spent in a parked car was 42 seconds. They also found that the duration was affected by factors such as the driver's gender, the time of day, and the distance from the parked vehicle to the destination.

C. Effect on Commuters

Reference [3] & [11] elaborates how Parking Management Systems affect the daily lives of commuters and expands on the notion on why it is essential. The study shows a typical survey that used different statistical analyses like linear regression to see the relationship between factors that affect parking. This study shows the increasing crisis of congested traffic and lack of parking spaces with better technology or conditions. It also says that urban planning should play a big part in solving these problems. Proper planning allows the roads and areas to be efficiently used through the years. The literature suggests that the factors that need attention are ease of access, walking time, parking charges, parking guidance, and information system and management. Open access parking systems can help reduce the problem of parking by allowing unused space in a lot to be used by others depending on the time and building use. It says that organizations and institutions could give access to other vehicle owners to maximize the parking space in an area.

III. METHODOLOGY

A. Method of Research

The study is categorized as a developmental type of research. Developmental research is the methodological study of creating, developing, and reviewing educational processes, products, and programs that must adhere to internal consistency and effectiveness. A system displaying information on available parking spaces was developed for the study. The system was capable of reserving parking spaces and redirection to another space when the initial was full. The study seeks to aid private vehicle drivers in the navigation of parking spaces.

B. Conceptual Framework

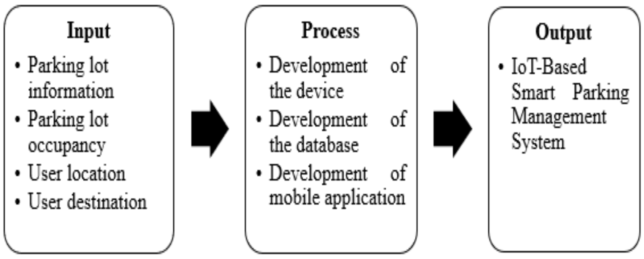

Fig 1 Conceptual Framework

The system is composed of a device, database, and mobile application. Information on parking lots and spaces is inserted into the database and displayed on the application. The occupancy of the parking space is detected by the device and is updated in the database. This occupancy is reflected in the LED indicators on the device and the application. The location and destination of the user are taken by the application and updated in the database. When a reservation is made, it is reflected in the device and the application.

C. Sensor System

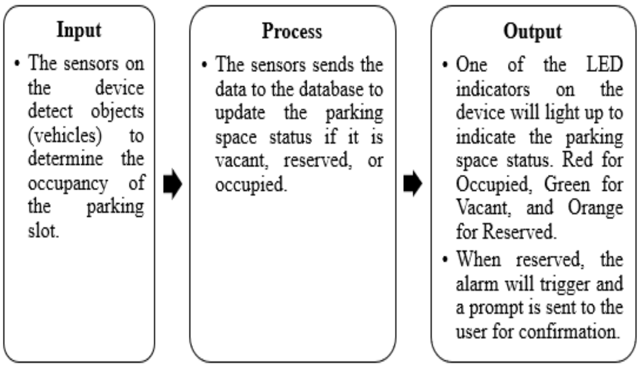

Fig 2 Block Diagram of the System Development

The sensors on the device of each parking space were able to detect the o of the space. The detected status of the space is sent by the ESP32 microcontroller of the device to the system's database. When the sensors do not detect the presence of a vehicle, it is considered vacant. The green LED indicator of the device lights up. When the presence of a vehicle is detected, it is considered occupied. The red LED indicator of the device lights up. When a reservation is made, the orange LED indicator of the device lights up. When the sensor on the reserved parking space detects a vehicle, a prompt to the user is sent for confirmation. When confirmed, the red LED lights up. When not confirmed, the alarm is triggered.

The ESP32 was connected to the ultrasonic sensors that allowed the system to detect a vehicle in front of it. The system logic is that if the value of the ultrasonic sensor returns as less than 30cm, the slot is occupied; else, the slot is vacant. LED indicators were also installed to indicate the status of the slot. Red showed that the slot was occupied, green showed that the slot was vacant, and orange showed that the slot was reserved. The status of the slot was determined by cross-referencing the value stored in the ESP32 and the cloud database. When the two values agree, the LEDs show the stored status.

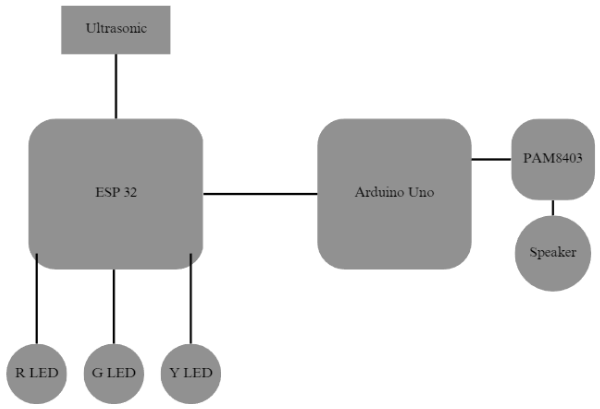

Fig 3 Interfacing of the components

D. Alarm System

An alarm system was installed in the system. The Arduino Uno and four speakers comprised this. One speaker was installed per system. The Arduino Uno and the ESP32 triggered the alarm—the microcontrollers communicated by mode of software serial communication. The RX and TX pins of the Arduino uno were connected to the digital pins of the ESP32. The alarm triggered when a reserved slot was occupied by an unauthorized vehicle. Once the reserved slot is occupied, a prompt to confirm the identity of the detected vehicle is issued. If the vehicle was confirmed to be the one that was reserved and yes was selected in the prompt, the alarm will not trigger. But suppose the vehicle was determined to be unauthorized, and no was selected in the prompt. In that case, the database will change the user's confirmation to no. The ESP32 was alerted and was to send a signal to the Arduino Uno to trigger the speaker of the concerned parking slot. Once the slot is vacated and detected by the ultrasonic sensor, the ESP32 updates the database that it is vacant, and the alarm is turned off.

E. Mobile Application

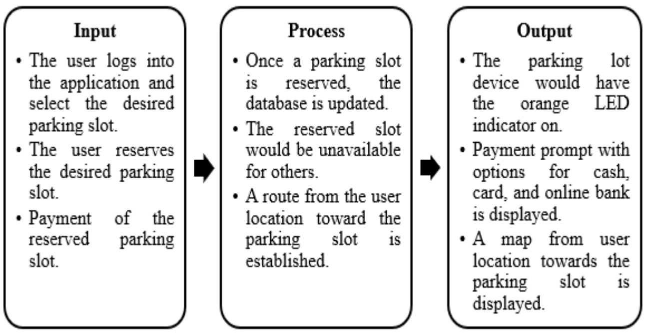

Fig 4 Block Diagram of Mobile Application Development

The application was developed with various software. Angular 14 NX was the Integrated Development Environment (IDE) mainly used to develop the application. The software allowed the compilation of the various files needed to make the application. Capacitor was the library used to ensure that the application was cross-platform capable. The application used for programming was Virtual Studio Code (VS Code). The application was only available for Android; however, a web application was available. IOS applications had many permissions and processes that needed to be paid, configured, and approved for before they could be made. Android Studio was the software used to build the application's Android Package Kit (APK).

A static map was installed in the application. It displayed the user's location and the route toward the parking lot. A dynamic map was shown when the map was held, and the prompt expand or view in google maps was clicked; the google maps application was launched, and the dynamic view of the map was displayed. Two accounts are present in the application, the admin account, and the user account. The admin account was for the monitoring of the online payments that have been made through reservations. The user account was for using the application to check, monitor, and reserve the parking slot.

When the application is launched, a login screen appears; once logged in, a map of the area and available parking lots are shown. A parking slot can be selected. Once a parking lot is selected, the available parking slots are displayed along with their available, vacant, or reserved status. The option to reserve a slot or proceed without the reservation is presented. Once the parking slot is reserved, a payment prompt will appear with online or cash payment options. Once payment is settled, the device in the parking slot will light up the orange LED indicating that the slot is reserved. Directions toward the selected parking lot are displayed in the application as a static map. The dynamic app can be triggered by holding the map and clicking the "view on google maps" option. The google maps application is launched, and the dynamic view of the map is displayed. Upon arrival in the parking slot and its detection by the system, the application displays a confirmation prompt asking if the correct person occupied the slot. If no is selected, the alarm system is triggered. The red LED is on if yes is selected and the slot status is occupied.

F. Smart Feature Integration

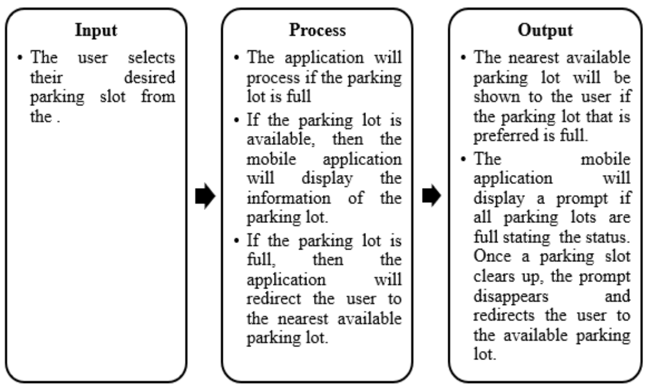

Fig 5 Block Diagram of the Redirection Feature

The general framework of the smart redirection feature of the mobile application is shown. The application will find the nearest available parking lot when the user's preferred parking lot is full. The mobile application will redirect the user to the nearest parking lot.

A user chooses a parking lot from the map shown in the mobile application. The mobile application will proceed to the booking screen when the user chooses an available parking lot. When the user chooses a full parking lot, the mobile application will find the nearest available parking lot for the user, and a prompt will appear. The mobile application shows a prompt indicating that the parking lot chosen is full and recommends the nearest available parking lot from the map. If the user clicks on cancel, the mobile application displays the summary of the nearest available parking lot and is highlighted on the map. If the user presses confirm, he's redirected to the booking screen.

IV. RESULTS AND DISCUSSION

Tests were conducted to evaluate the functionality and achieve the objectives set by the proponents.

Table 1 Accuracy of the system to detect and display the status of the device

Expected Status	Device LED Lit	LED light Meaning	Remark
Vacant	Green	Vacant	Match
Occupied	Red	Occupied	Match
Reserved	Orange	Reserved	Match

Table 1 shows the test to prove the accuracy of the device to detect and display the status of the device. As observed, the expected status is a match with the LED light meaning that the test was a success, and the device works properly. The LED lights up depending on the status of the device.

Table 2 Accuracy of the mobile application to detect and display the status of the device

Expected Status	Mobile application status	Remark
Vacant	Vacant	Match
Occupied	Occupied	Match
Reserved	Reserved	Match

Table 2 shows the test to prove the accuracy of the mobile application to detect and display the status of the device. As observed, the expected status is a match with the mobile application status which means that the test was a success, and the mobile application works properly. This also means that communication with the mobile application and the device works properly.

Table 3 Response time of the device to display the parking slot's status in seconds

Trial	Device 1	Device 2	Device 3	Device 4
1	6.85	6.30	8.08	6.85
2	7.11	10.84	6.14	5.88
3	7.47	8.19	12.54	3.18

Table 3 shows the response time of the device to display the parking slot's status in seconds. This is the data that has been collected during testing. The response time recorded in the table is very well set within the criteria that has been set by the proponents. This is given a pass since the criteria of less than 20 seconds has been met. This is also shown in the SQA test below.

Table 4 SQA Test of Response Time

Performance Objective	Metric	Success Criteria	Result
Response time of the system to update the parking slot's status	Seconds it took to update the prototype's LED indicator light	<20 seconds	PASSED
Response time of the database to update the parking slot's status	Seconds it took to change the "status" node of the database	<10 seconds	PASSED
Response time of the mobile application to update the parking slot's status	Seconds it took to change the status of the slot in the application.	<10 seconds	PASSED

Table 4 shows the SQA test conducted. [8] The criteria that have been set are shown here. As recalled from table 3, the data follows the set criteria of the SQA test and therefore has been given a pass. The criteria set here is based on the related literature about parking behavior. [9], [10] & [13]

Table 5 Number of successful and failed reservations made through the mobile application

Reservations	Succeeded	Failed
160	160	0

Table 5 shows the number of successful and failed reservations made through the mobile application. As seen above, the number of reservations made matched the number of successful reservations and there were 0 failed reservations. Therefore, it can be concluded that the mobile application's reservation feature is working flawlessly.

Table 6 Instances of users diverted to the nearest available parking lots due to full lots

Full lots	Free lots	Diverted to nearest parking lot?				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
1	3	Success	Success	Success	Success	Success
2	2	Success	Success	Success	Success	Success
3	1	Success	Success	Success	Success	Success

V. CONCLUSION

An IoT-based Smart Parking Management System is a system with devices installed in parking lots. Its functionality was to detect whether a specific parking slot was available, occupied, or reserved. It also has a mobile application that displays information about the available parking lots around the area and allows users to reserve parking slots ahead of time. It also had a smart feature that allowed the diversion of the best possible parking lot within the chosen area.

The system that was developed using ultrasonic sensors as a main sensor for identifying the status of the parking slot was discovered to be accurate. The results of the tests indicated that the system was very capable of detecting the status of the parking slot. It was found that the system had 100% accuracy. The system is also successfully connected to the mobile application, which highlights that the IoT capabilities of the system are successful. The system's response time to change the system's status or the LED lights was also a success. This was acceptable since, according to the Software Quality Assurance (SQA) test that was performed, the system had passed its standardized criteria. The alarm system had performed properly and sounded accordingly.

The mobile application that had been developed performed perfectly in showing the information about the available parking lots. Based on the data and results of the testing that had been conducted, the mobile application perfectly displayed the correct information about the parking slot. The reservation feature has also been successfully integrated. The data suggested that the reservation feature had been successful because all the reservation requests had been accepted. The prompt shows immediately when there is a vehicle in a reserved slot. The response time was also acceptable because the SQA test suggests that the criteria set for the mobile application to respond and change its status accordingly had been given a passing remark.

The "Smart" feature also was discovered to be successfully integrated. The results of the testing that had been performed with the mobile application suggested that the mobile application will always find the best available parking lot for the user if the chosen parking lot was said to be full. Four scenarios have been done: 1 full parking lot, 3 available parking lots; 2 full parking lots, 2 available parking lots; 3 full parking lots, 1 available parking lot; and all parking lots are full. The data suggested that the mobile application found the best available parking lots for all scenarios. However, the scenario where all parking lots are full shows a prompt that signals to the user that all parking lots are currently full, and that the user tries to book again in a few minutes.

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