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Development of Automated Parking System with UHF-RFID & Application

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***Abstract*— The increasing demand for parking space, driven by the rapid growth of car ownership, has exacerbated traffic congestion and urban planning challenges worldwide, including the Philippines. To address these issues, this study developed an Automated Parking System (APS) to manage and assist vehicles in designated parking areas through the integration of hardware circuitry, mobile applications, and cloud-based web systems.**

The study utilized a descriptive-developmental research design and followed the System Development Life Cycle (SDLC) methodology. The APS system was prototyped using components such as Node MCU V3 ESP8266 controllers, RFID readers, ultrasonic sensors, and cloud connectivity via Firebase Realtime Database. The system design included schematic diagrams, circuit layouts, data flowcharts, and a mobile application interface. Solar panels provided power, while weather proof enclosures protected the hardware.

System evaluation, based on ISO/IEC 25010 standards, measured the system's Functional Suitability, Performance Efficiency, Usability, Reliability, and Security. The APS system achieved high user satisfaction across all criteria, with weighted means of 4.0, 4.12, 4.35, 4.22, and 4.45, respectively, indicating its functionality, efficiency, reliability, and security.

The findings demonstrate the APS system's potential to mitigate parking challenges and improve urban transport efficiency. Recommendations for enhancing the system include increasing antenna height for better connectivity, improving master station reliability, and integrating the APS system into digital city initiatives for broader applicability.

Index Term: **parking system, SDLC, NODE MCU, RFID, UHF**

I. INTRODUCTION

The increase in car ownership, from 6.5 million in 2008 to 7.61 million in 2019 in Belgium, exacerbates the demand for limited parking space, leading to heightened traffic congestion and challenges for urban planners in managing parking effectively. Increasing car use leads to a demand for more parking spaces, which restructures cities to prioritize vehicles over public transport and pedestrian access. This results in urban sprawl, reduced community interaction, and increased air pollution, exacerbating transport problems. In the Philippines, rapid car ownership growth in urban areas leads to a significant imbalance between parking supply and demand, resulting in parking shortages, high tariffs, and increased traffic congestion as drivers search for available spaces. Car ownership under road and parking constraints, emphasizing that increased parking spaces do not necessarily lead to higher car ownership if road links are saturated, highlighting the need for effective resource distribution in urban planning. [1][2][3][4] The average time spent searching for parking in France is significant, with estimates of 70 million hours annually, costing around 700 million euros. This includes externalities like noise and pollution, highlighting the need for effective parking management strategies. The mean parking search duration is 1.5 minutes, with large city centers averaging 1 minute and 53 seconds. This duration is significantly lower than previous survey-based estimates, indicating potential biases in traditional parking search surveys. The average time spent searching for parking exceeds dozens of hours per driver annually in many Western cities, contributing to cruising traffic, pollution, and congestion, highlighting the significant impact of parking search time on urban transport policies. [5][6][7].

In the Philippines, it indicates that the average search time for parking is about 6.03 minutes, which may be relevant to similar urban contexts. [8]

With this gap considering, the Automated Parking System is a system that will manages and assists the vehicle or drivers to designated parking areas with the use of developed hardware circuitry, mobile and cloud web applications. Given its potential to alleviate parking congestion and improve the efficiency of parking operations. A community parking space sharing system aimed at improving parking space usage, addressing limited parking issues. [9]

II. RESEARCH OBJECTIVES

The general objective of the study is to develop an automated parking system that manages and assists drivers and vehicles into designated areas by utilizing mobile and cloud web applications. Specifically address the following objectives:

1. Design and developed the APS hardware components.
2. Developed a cloud base database for APS system.
4. Developed a mobile application for APS system.
5. Evaluate APS system in accordance with ISO/IEC 25010 Standards to evaluate the end-user experience in terms of the criteria below:
5.1 Functional Suitability
5.2 Performance Efficiency
5.3 Usability
5.4 Reliability
5.5 Security

The research is wide-reaching and had significant to the following main users such as car owners or operators, parking attendants, employees that work in an APS ready car park facility, urban planners and policy makers and the society as a whole.

III. METHODOLOGY

The researchers utilized a descriptive- developmental forms of research design and utilized the System Development Life Cycle (SDLC) model in designing, development, iteration and evaluation of the system. The (SDLC) method is a structured approach to development, which includes planning, analysis, design, implementation, and maintenance phases for effective application functionality and user experience. [10] This method was a conceptual model used in project management that described the stages involved in a development project, from an initial feasibility study through maintenance of the completed application.
The prototype approach was utilized by the researchers to develop the system. Prototyping is a constructionist model emphasizing "learning-by-making," facilitating innovative concept development in design. It serves as a tool for experiments, participatory design, and user-centered design, while embodying both coded and tacit knowledge, challenging explanation to non-designers. [11] The prototype model illustrated the project development process in a basic bending flow. This means that any phase in the development process begins after the previous stage was completed.

Figure 1 shows the Prototype Model of SDLC that the researchers used with project respective phase.

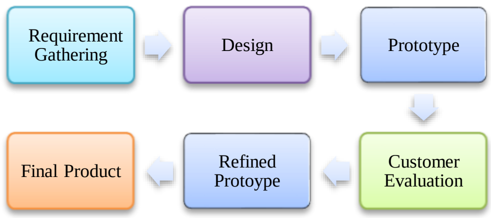

Figure 1. System Development Life Cycle Prototype Model.

A. Materials

The materials used for prototype development were readily available in the local market. The material includes Node MCU V3 ESP8266 which served as the main controller of the different system components like RM9002 RFID Reader, Ultrasonic Ranging Module, IP68 Waterproof Outdoor Modem External Antenna, P10 high brightness 5V dot matrix display outdoor LED module, RFID RC522 Module, Industrial Electronic Alarm Buzzer Siren and router. An Arduino IoT module was utilized on this project to connect the system to IoT cloud server. The application (App) developed as software components to process the data collected from the sensors where push-on notification activated once the set criteria has been met.
The system used Firebase Realtime Database to store and syncs data in real time, it contains the user accounts registry, status of the parking area if available and its groupings.

The RFID determined the number of slots available in the area and send it over to the cloud and display it to the app, the system will let the user select the designated parking space for him/her to reserve, the system will designate time for the user to physically be in the parking space and verify his/her identity with the RFID user data on the database, if not identical the reservation will be invalid.

Solar panels and storage battery were used to power up the system. IP 66 or NEMA 4X enclosure will serve as the housing to protect the circuitry, the hardware components and storage battery.

B. Design

After gathering phase, the researchers proceeded to design the possible circuitry that was used in implementation of the research project. The researchers created a framework of the system that satisfied the device's functionality. Data flow charts were made to identify the inputs and output of the system. Block diagrams and Schematic Diagrams were also made along the maintenance phase and applied to the design.

Figure 2 shows the system block diagram, it illustrates the system process.

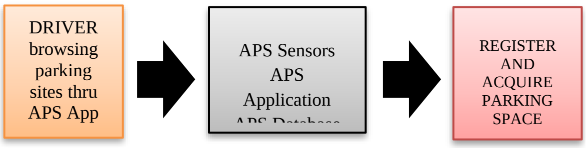

Figure 2. The system block diagram.

Figure 3 shows the hardware circuit simulation on the main components of the system.

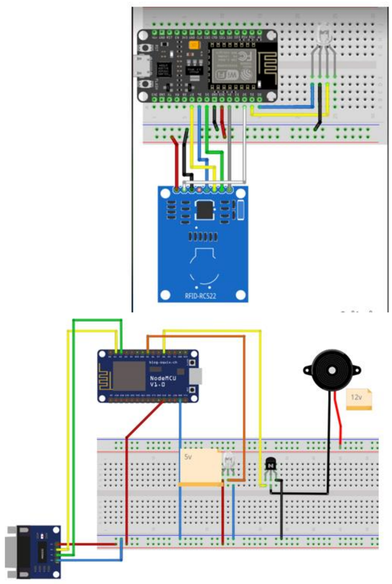

Figure 3. Hardware circuit simulation

Furthermore, Figure 4 shows the system flowchart for APS-1, this served as the basis programming codes of the system.

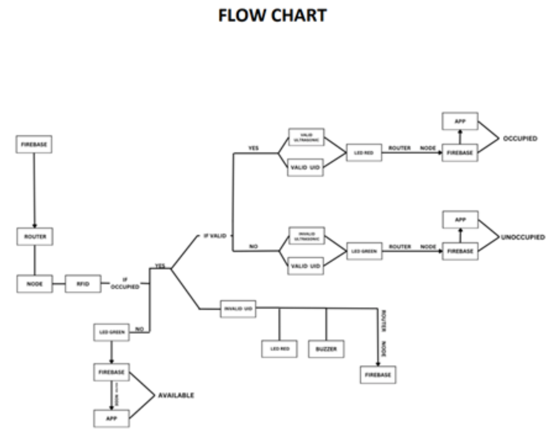

Figure 4. System Flowchart APS-1

Figure 5 shows system flowchart for APS-2

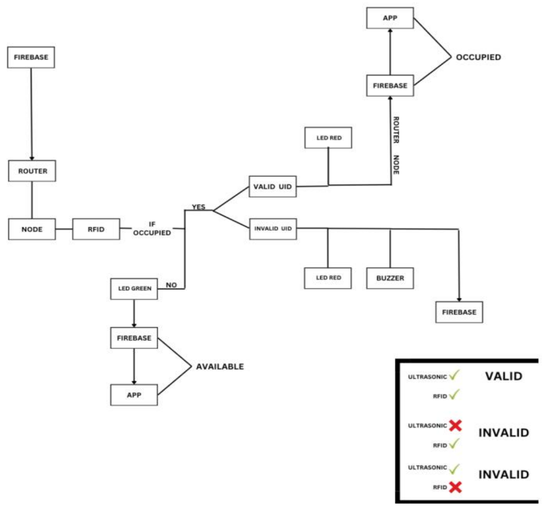

Figure 5. System Flowchart APS-2

C. Prototype Development

With the design finalized, the researchers proceeded to the prototyping phase of the research project. This stage encompassed the development of the final hardware design, which included detailed device schematic diagrams, circuit layouts, connection configurations, the mobile application interface, and the enclosure design.

Figure 6 shows the APS Master Station that facilitates connectivity to all APS Slave stations.

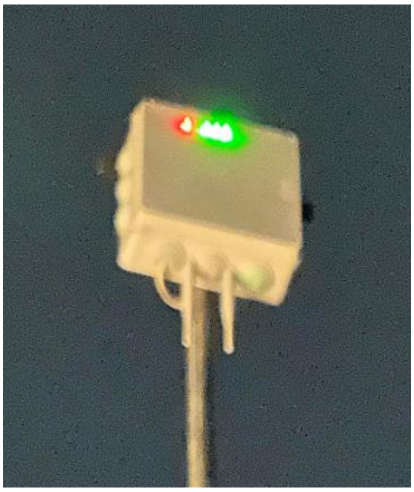

Figure 6. APS Master Station

Figure 7 shows the APS Slave station, this facilitates the parking condition on site.

Figure 7. APS Slave Station

Figure 8 shows the developed system application dashboard. This app facilitates the user registration and account on the APS system.

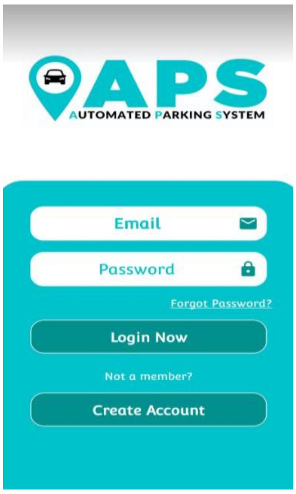

Figure 8. APS Application Interface

D. System Iteration

The connectivity time delay parameter of the APS system was evaluated between the master and slave stations as a function of distance, as illustrated in Figure 9. The researchers conducted three trials at varying distances between the slave station and a master station equipped with a 20-foot antenna. The data indicates a positive correlation between the time delay and the distance of the slave station from the master station.

Using the collected data, system iterations were performed to determine the maximum operational distance of the farthest slave station within the APS system

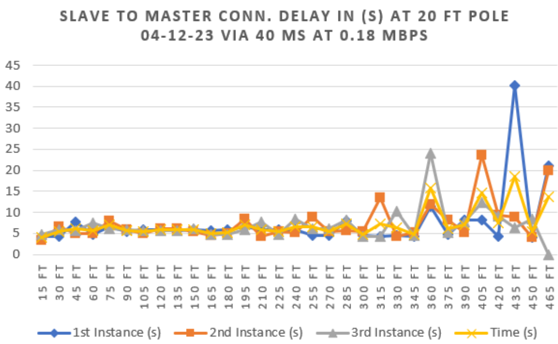

Figure 9. APS System test results

E. System Evaluation

The researcher utilized ISO ISO/IEC 25010 to evaluate the core functions of the system which includes the following criteria, functional suitability is how well a system meets its functional requirements. Performance efficiency is how well a system performs under various conditions. Usability is how easily a system can be used to achieve goals with minimal effort. Reliability is how consistently a system performs its intended functions without errors or disruptions for a specified period. Security is how a system has the degree of data access appropriate to their types and levels of authorization [12].

The system evaluation questionnaire used five-point (5) Likert scale with the interpretations as shown in Table 1.

Weighted Mean	Likert Scale	Legend
4.21-5.00	5	Strongly Agree
3.41-4.20	4	Agree
2.61-3.40	3	Neutral

1.81-2.60	2	Disagree
1.00-1.80	1	Strongly Disagree

Table 1. Likert Scale

Based on ISO ISO/IEC 25010 system criteria, Table 2 shows the results of the user evaluation of the APS system.

System Criteria	Weighted Mean	Verbal Description	Verbal Interpretation
1.Functional Suitability	4.0	Agree	Functional
2.Performance Efficiency	4.12	Agree	Efficient
3. Usability	4.35	Strongly Agree	Very Useful
4. Reliability	4.22	Strongly Agree	Highly Reliable
5. Security	4.45	Strongly Agree	Very Secure

Table 2. User Evaluation on APS system

IV. RESULTS AND DISCUSSION

A. Conclusion

Based on the data gathered and analyzed, the following conclusions were established:

1. The researchers successfully designed and developed the hardware components of the APS system.
2. A cloud-based database for the APS system was developed using the Firebase Realtime Database platform.
3. A mobile application for the APS system was created utilizing IoT Cloud software.
4. The evaluation of the APS system across various quality criteria yielded the following results: The Functional Suitability criterion achieved a weighted mean of 4.0, corresponding to the verbal interpretation of "Functional." For the Performance Efficiency criterion, the system obtained a weighted mean of 4.12, interpreted as "Efficient." Under the Usability criterion, the system scored a weighted mean of 4.35, which is verbally interpreted as "Very Useful." In terms of Reliability, the system garnered a weighted mean of 4.22, classified as "Highly Reliable." Lastly, for the Security criterion, the APS system achieved a weighted mean of 4.45, interpreted as "Very Secure."

B. Recommendation

The researchers proposed the following recommendations for further improvement and development of the APS system:

1. To enhance the distance coverage between the APS master and slave stations, it is recommended to increase the antenna height of the master station.
2. Improvements in the connectivity of the APS master station should be prioritized to ensure more reliable communication.
3. For future development, the integration of the APS system into the Department of Information and Communications Technology's (DICT) plan for a digital city is encouraged.

REFERENCES

[1] Adetola, Aroloye. Parking Policies to Reduce Car Use and Congestion in Urban Areas. Social Science Research Network, doi: 10.2139/ssrn.4605119

[2] Hermann, Knoflacher. (2006). A new way to organize parking: the key to a successful sustainable transport system for the future:. Environment and Urbanization, doi: 10.1177/0956247806069621

[3] H., Ibrahim. (2017). Car Parking Problem in Urban Areas, Causes and Solutions. Social Science Research Network, doi: 10.2139/SSRN.3163473

[4] Mei-Lam, Tam., William, H., K., Lam. (2000). Maximum car ownership under constraints of road capacity and parking space. Transportation Research Part A-policy and Practice, doi: 10.1016/S0965-8564(98)00070-6

[5] A, Le, Fauconnier., E, Gantelet. (2006) The time looking for a parking space: strategies, associated nuisances and stakes of parking management in France.

[6] Siavash, Saki., Tobias, Hagen. (2024). Cruising for parking again: Measuring the ground truth and using survival analysis to reveal the determinants of the duration. doi: 10.1016/j.tra.2024.104045

[7] Nilankur, Dutta., Thibault, Charlottin., Alexandre, Nicolas. (2022). Parking Search in the Physical World: Calculating the Search Time by Leveraging Physical and Graph Theoretical Methods. Social Science Research Network, doi: 10.2139/ssrn.4019954

[8] Yating, Zhu., Xiaofei, Ye., Jun, Chen., Xingchen, Yan., Tao, Wang. (2020). Impact of Cruising for Parking on Travel Time of Traffic Flow. Sustainability, doi: 10.3390/SU12083079

[9] Wang, Mingwei. (2013). Community parking space sharing and use reserving service system based on vehicle identification.
[10] Andi, Muflihah, Darwis, Andi., Jesson, Jesson., Kevin, Prabevi, Kevin., Melvin, Lie. (2023). Perancangan Aplikasi Chatting Symmetric Encryption dengan Metode SDLC. Telcomatics, doi: 10.37253/telcomatics.v8i1.7385
[11] Brian, Lee. (2020). Prototyping: The Dual Actions. Cubic journal, doi: 10.31182/cubic.2020.3.024
[12] ISO25000, 'ISO/IEC 25010 Standards', Software Product Quality. https://iso25000.com/index.php/en/iso-25000-standards/iso-25010?start=5