Technology Adoption and Human Interaction in Smart Parking Systems Using QR Code Access

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ABSTRACT

This project tackles common problems in traditional parking systems, such as long search times, manual processes, and inefficiencies, especially in busy areas. To address these issues, we developed a smart parking system that uses QR code technology to automate and secure vehicle entry and exit. The system features a website application that lets users register, view available parking spots in real time, and manage access without needing to download any mobile apps. The smart parking system improves parking management by allowing real-time tracking of slots, reducing the need for human involvement, and enhancing traffic flow. It decreases congestion at entry and exit points through automation, which significantly cuts down waiting times. Users enjoy a convenient, contactless experience, while operators benefit from better use of slots, lower operational costs, and reliable data for planning and assessment. Key hardware components include ESP8266 and ESP32-CAM microcontrollers, IR sensors, a display, a servo motor, LED indicators, and a buzzer, all linked through a local Wi-Fi network. Users register on the website, scan a QR code at the entrance using their phone browser, and receive a parking slot. After payment is completed, a unique QR code is generated for exiting the parking area. Testing showed that the system achieved 100% reliability in all main functions, proving its efficiency and ease of use. The solution is low-cost, scalable, and user-friendly, making it appropriate for real-world settings like campuses, malls, and public parking facilities. In conclusion, this smart parking system offers a practical and effective way to modernize parking management, with strong potential for future improvements, such as integrating payment gateways and mobile applications.

Keywords: Internet of Things (IoT), NodeMCU, Parking System, Web Application

INTRODUCTION

In today's rapidly growing world, the number of individuals acquiring driving licenses continues to rise significantly. As a result, the volume of vehicles on the road has also surged, leading modern cities to encounter various challenges. One major issue is traffic congestion, particularly during peak hours when roads are heavily crowded. In addition to that, finding an available parking space has become increasingly difficult. In many high-traffic urban locations, the lack of parking often results in long delays and driver frustration, as the search for a vacant spot becomes nearly impossible.

Finding the right car parking in contemporary cities is viewed as a problem in terms of a drag on time as well as power consumption (C. Biyik et. Al., 2021). X. Xiao et al. (2021) said that on average, it takes individuals roughly 20 minutes of their valuable time to get a parking space. Nowadays, there are several car park guide systems using different technologies to resolve the parking problem in the car park. For example, give a website for creating graphical user interfaces (GUIs) for internet connectivity and Internet of Things (IoT) administration (J. A. Abdulsaheb et. al,2024). The combination of various technologies has allowed the system to be more convenient to use, as the customers can find a parking spot in less time and with minimal effort. One of these technologies is the application of Quick Response (QR) codes, which has been beneficial in smart and urban city landscapes, allowing access to the necessary functions digitally, including checking the availability of parking slots, payment, vehicle entry, and exit.

M. Fokhrul et. al. (2024) proposed a system using QR code that assists in retrieving user information and cross-referencing it with the database. Besides, QR codes are convenient to implement in applications because they can easily be scanned with the help of users or vehicles as compared to traditional access solutions, which include physical tickets or cards. This reduces dependence on hardware-based systems. This project introduces a smart parking solution that utilizes QR code technology to address common inefficiencies and enhance user accessibility. By combining the ease of QR code usage with modern parking infrastructure, the system supports broader goals related to sustainable and efficient urban development.

In this proposed study, a parking platform is accessible only to drivers who have registered. After registration, the QR code is scanned for entrance. On arrival, the driver scans the QR code using the website application. The website will then prompt the driver to enter the vehicle. Using a Website Application (WebApps), the driver must pay for parking before exiting. This mode eliminates not just the reliance on hard currency but also minimizes human involvement in cash processing. Cashless payments speed up revenue collection while reducing operational overheads for parking companies. Thirdly, after payment is completed, the website app will generate a QR code that the driver can use to unlock the exit gate by presenting it to the ESP32-CAM camera. In the long run, this speedily sustains more efficient use of resources.

RELATED STUDIES

This chapter reviews the findings of prior publications concerning the application of Quick-Response codes (QR), ESP32 cameras, and ESP8266 microcontrollers in parking systems. The review centers on how each of these technologies works together in improving operations, users, and the system as a whole. For these reasons, QR codes quickly became appreciated as a simple, contactless means to organize the user interface, as well as for identification and access management (N. A. Abd Rahman et. al,2022). Similarly, the ESP32-CAM module is equipped with both image-capturing capabilities and built-in Wi-Fi, allowing it to transmit data in real time. Meanwhile, the ESP8266 microcontroller functions as a reliable platform for managing communication tasks and processing data within the Internet of Things (IoT) environment.

Identification Devices

M. Fokhrul et. al. (2024) proposed parking slot detection systems by providing an easy and efficient way to manage parking access using a Quick-Response code (QR) code reader. Users complete registration and reserve a parking space through a website-based platform. This approach enhances security by limiting access, ensuring that only verified users are allowed entry. Once a reservation is made, the system generates a QR code that serves as a unique identifier for the user's transaction, helping to prevent theft and unauthorized vehicle access.

Kanumuru R. et. al (2018) described an original system using QR codes for the orientation of vehicles in indoor car parks, in real-time. The proposed framework greatly improves parking management because accurate vehicle positioning enables easy identification of stored vehicles. In addition, N. A. Abd Rahman et. al. (2022) developed a secure parking and reservation system that combines the use of car plate recognition and QR code technology. This modern system enhances both the security and efficiency of parking operations by automating card-based access along with the reservation and release of parking spaces within the facility.

Lastly,Z. Li et. al (2022) proposed that the parking guidance and vehicle retrieval system offers an efficient solution by using QR codes to streamline parking management. The QR codes are scanned at the different phases of the parking process, and each has a particular purpose to fulfil. On entering the parking area, the user scans a code which provides them with a map outlining the available spaces and how to navigate to a specific space they have decided to take. Once parked, further use of a QR code stores the location where a vehicle is parked in preparation for future retrieval. Users can also scan car-finder QR codes in strategic locations where they pick their cars to get guidance back to where they park their cars.

Parking System with Web Application

Lubna et al (2023) proposed of interfacing web solutions in smart parking systems to enhance via IoT has greatly improved the access and control of the user interface. User interfaces play a crucial role in this layer by enabling individuals to manage parking tasks, such as checking slot availability and making reservations, through web-based platforms or dashboards. The use of embedded JavaScript templates (EJS) is highlighted as a way to display real-time updates from databases like MongoDB, keeping users informed of current space availability. Moreover, the web frameworks developed in Python assist in communication through MQTT protocols, which also contributes to the reliability of the system. Even more, dashboard approaches at the entrances of the parking help the drivers proceed with fast and well-informed decisions. Comprehensively, such web interfaces facilitate the development of smart parking systems that are efficient, user-friendly and sustainable.

Additionally, N. A. Abd Rahman et. al. (2022) focus on the web-based interface in a secure parking system, demonstrating how user experience and effective parking management can depend on it. Another feature of the modern parking system is the ability to reserve parking places in real time, to see the parking history, and to make online payments (securely). User information is secured by a series of security systems, such as SSL encryption, CAPTCHA tokens, and two-factor authentication (2FA). Such systems usually offer interactive effects with their users by such as confirmation of bookings and live messaging. The access and exit are also made easier because of available tools such as the license plate identification and QR code scan, as they provide a convenient and safe authentication, which is flexible to ease the user experience.

J. Park et al (2022) proposed that the dynamic parking space allocation system web-based interface is well designed using the latest web development technologies like JavaScript, HTML, and CSS for an effective and user-friendly interaction. JavaScript is at the core of the interface of the system, making it interactive and having real-time data information on the parking slots. Its combination would mean that all alterations by the attached IoT devices, like the infrared sensors or RGB LEDs, would be immediately repackaged on the interface screens, and parking management would be able to monitor the parking field on a real-time basis. In the meantime, HTML determines the positioning of the web application, and groups together the distribution of the information to the users and administrators to have a satisfactory and user-friendly interface.

Having semantic tags and adopting a responsive design enables the HTML model to be perfectly compatible with diverse devices such as desktops and smartphones. CSS improves this flexibility and leads to a uniform and well-appearing interface. CSS does not only enhance the structure of the web site but also provides the stylistic peculiarities in the form of color-marking of parking-place status, following the motions, and the responsiveness of layouts-making it look and feel easier and compelling to use.

METHODOLOGY

The block diagrams for the Gate-In and Gate-Out processes represent the hardware architecture used in the QR-based smart parking system. As shown in Figure 1, the system integrates several input components, including IR sensors for vehicle detection and QR code scanning via a user interface, all powered by a 5V 2A adapter. These inputs are processed by a central microcontroller, which then triggers appropriate responses. The output components include LED indicators to show access status, a servo motor for gate operation, a buzzer for audio feedback, and an LCD screen to display messages to the user.

Figure 2 illustrates the overall operational flow of the system. Input devices such as IR sensors and manual interfaces send data to the microcontroller, which makes real-time decisions. Outputs like LEDs, servo motors, buzzers, and a web-based interface help automate the entry and exit process while keeping users informed. The integration of these components ensures an efficient, user-friendly, and fully automated parking system.

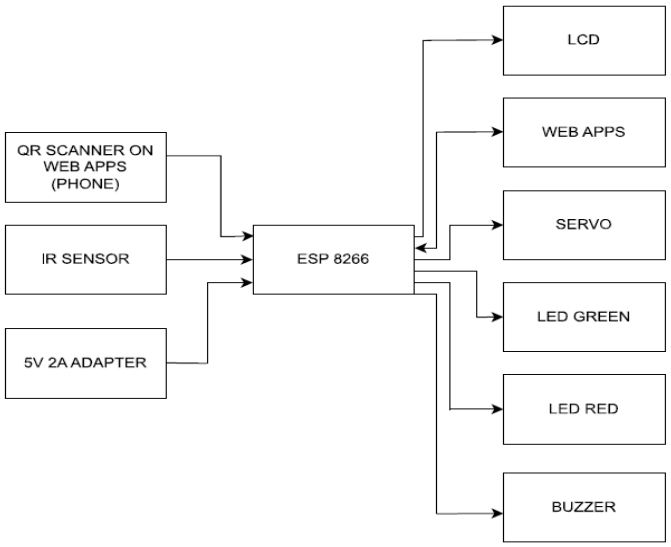


Figure 1: Block Diagram for Gate In system

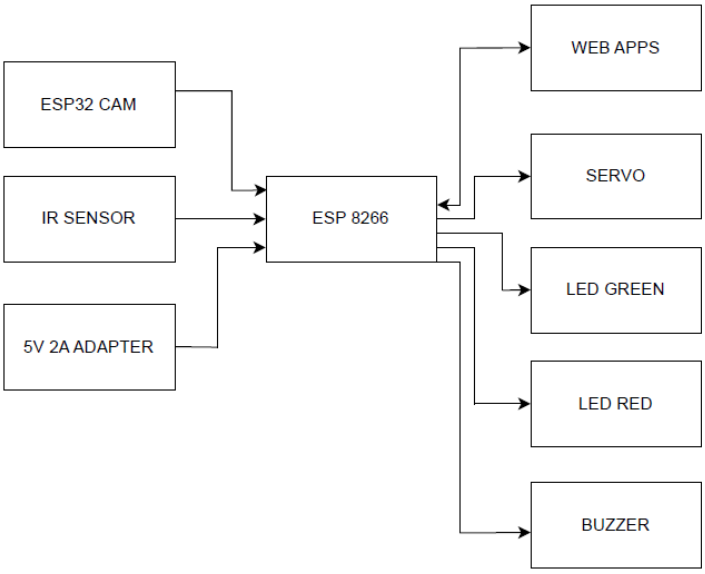


Figure 2: Block Diagram for Gate Out system

The gate control process begins with a 5V 2A adapter supplying uninterrupted power to the entire system via a female jack. The ESP8266 microcontroller serves as the core controller, managing communication between components. When a vehicle is detected by the IR sensor, a signal is sent to the ESP8266, which then verifies user access through QR code authentication linked to the database. Upon successful validation, the green LED lights up, the buzzer emits a confirmation tone, and the servo motor opens the gate.

An LCD screen simultaneously displays messages such as “Access Allowed” or available parking slot information. In the event of failed authentication, the red LED is activated, a denial tone is produced, and the gate remains closed, with the LCD providing appropriate feedback. All components operate in real-time and are synchronized by the microcontroller to ensure a fully automated and efficient parking management system, as illustrated in Figure 3.

Next, the gate-out system, as illustrated in Figure 4, begins with a 5V 2A adapter supplying stable power to all connected hardware components via female jacks. The ESP8266 microcontroller serves as the central controller, managing input and output operations. When a vehicle approaches the exit, the IR sensor detects its presence and sends the signal to the ESP8266. The ESP32-CAM then scans the QR code for verification. If authentication is successful, the green LED lights up, the buzzer emits a confirmation sound, and the servo motor activates to open the gate, allowing the vehicle to exit. The ESP32-CAM also captures visual data for

monitoring purposes. If the QR code is invalid, the red LED lights up, the buzzer alerts an error tone, and the gate remains closed. This sequence ensures secure, automated gate control with real-time feedback and minimal manual intervention.

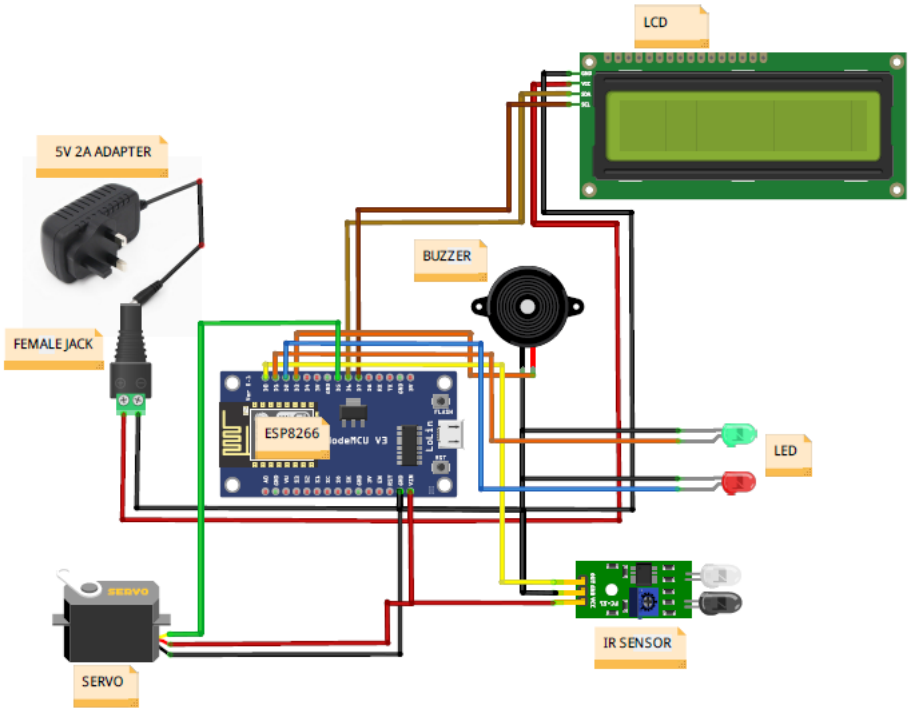


Figure 3: Schematic Diagram for Gate In system

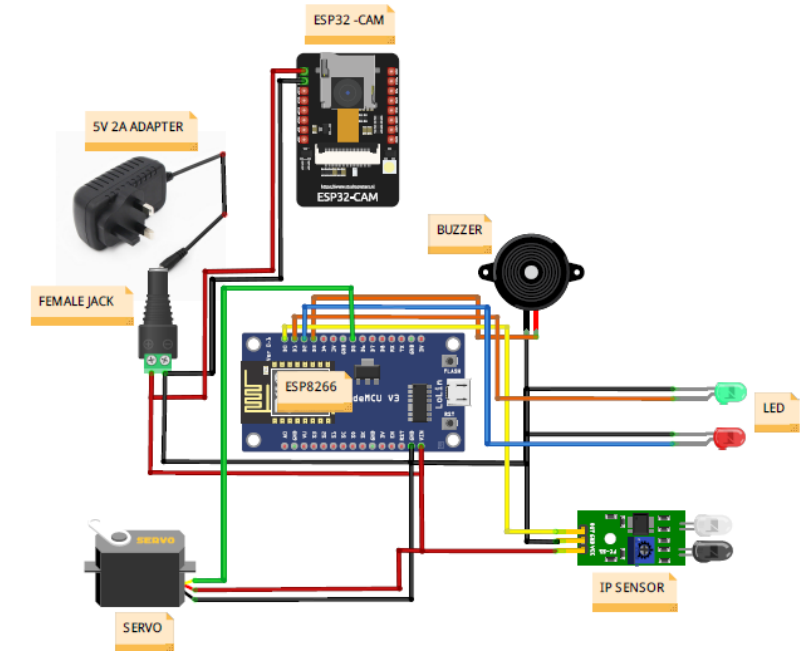


Figure 4: Schematic Diagram for Gate Out system

RESULTS AND DISCUSSION

This section provides an overview of the testing process, and the results obtained from evaluating the system's functionality and performance. The testing focuses on assessing the reliability, efficiency, and integration of the system's components to ensure seamless operation. Based on the outcomes, this section demonstrates the extent to which the system achieves its intended aims and prospects for its application.

Web Application Interface for Administration

The login page shown in Figure 5 allows both regular users and administrators to access the QR Parking System Website Applications. Once logged in, Figure 6 displays the QR Parking System's admin dashboard, paying special attention to the Parking Information Panel. This page displays real-time use of the parking spaces available. On the top part, the status of each parking bay is shown, for example "Parking 1", and icons show current condition which is this slot is occupied, a car icon will appear, while "Parking 2" until "Parking 5", an available slot is shown with a "P" icon. Also at the bottom, there is a detailed table that shows every user's parking information such as their name, phone number, vehicle plate number, allocated parking space, check-in time and parking charges. The panel is used by the administrator to find active users, review entries and calculate parking payment efficiently.

In Figure 7, the administrator can access detailed user data such as their name, phone number, identity card or passport, address and email. It becomes easy to follow and manage all the accounts in the system. Next, Figures 8 highlights that the "Receipt Token" section keeps track of topping up transactions. In this way, administrators can see the amount of credit users have and ensure that users only can access parking services when their balance is sufficient.

Lastly, for Figure 9 is devoted to "Parking Charge," showing the charge for parking at RM2 per hour. It means the administrator can modify or update the prices in use whenever necessary. All together, these sections help the admin with managing user accounts, tracking payments and making sure all charge rates are accurate in QR Parking System.

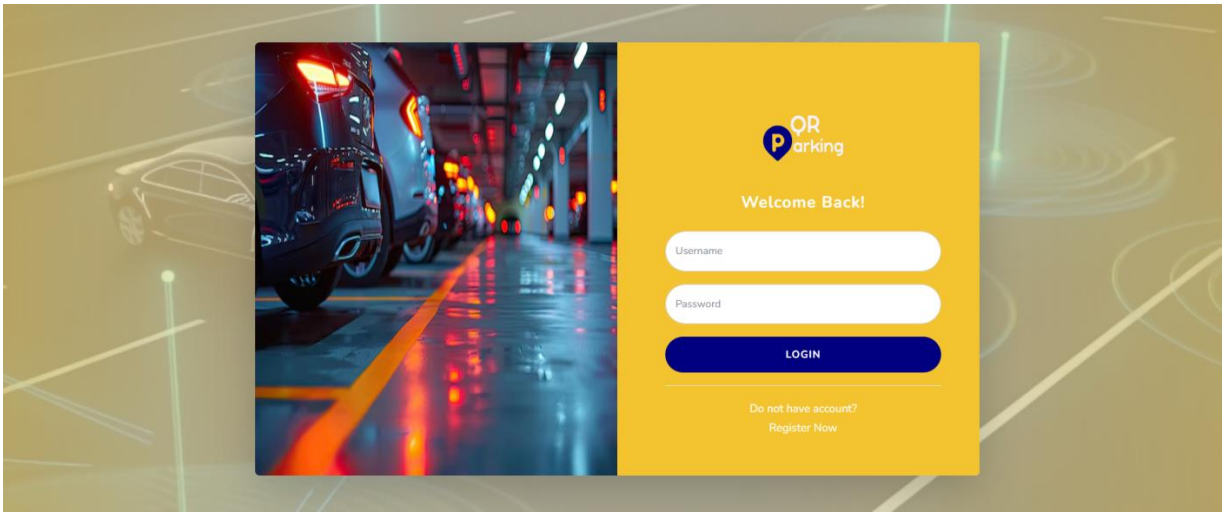


Figure 5: Login Page

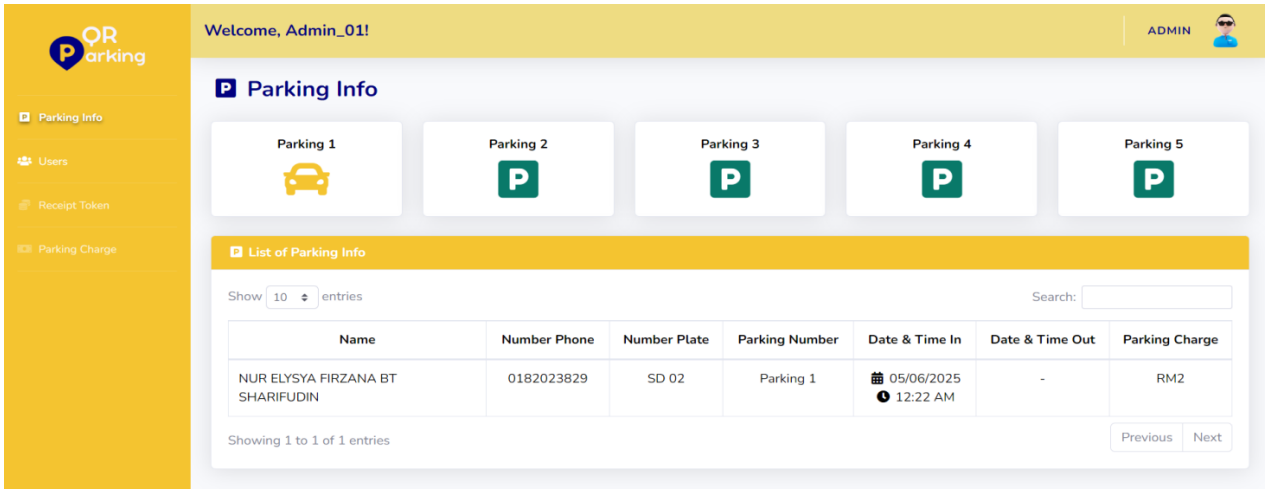


Figure 6: Parking Information

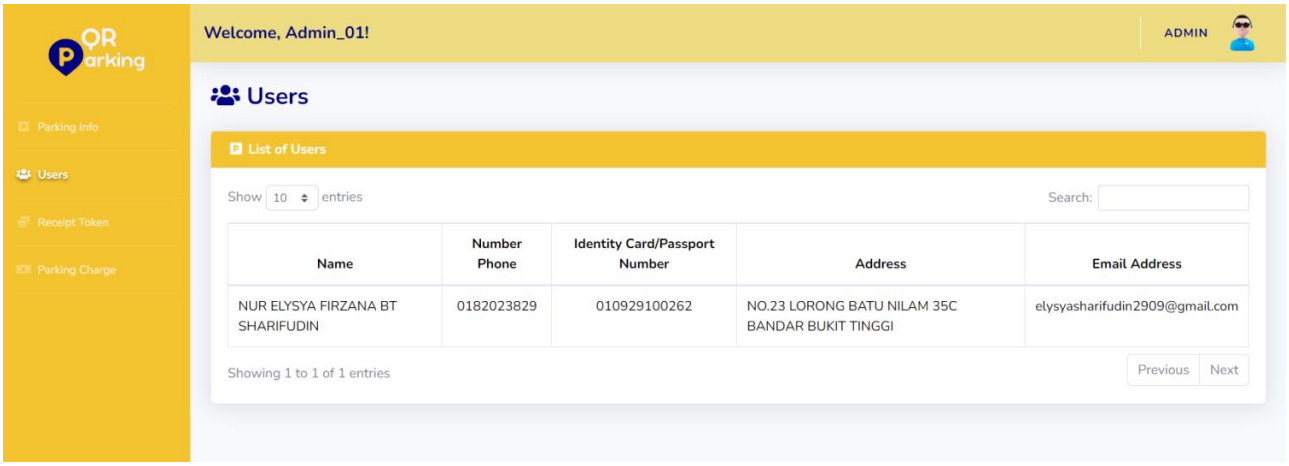


Figure 7: Registered Users List

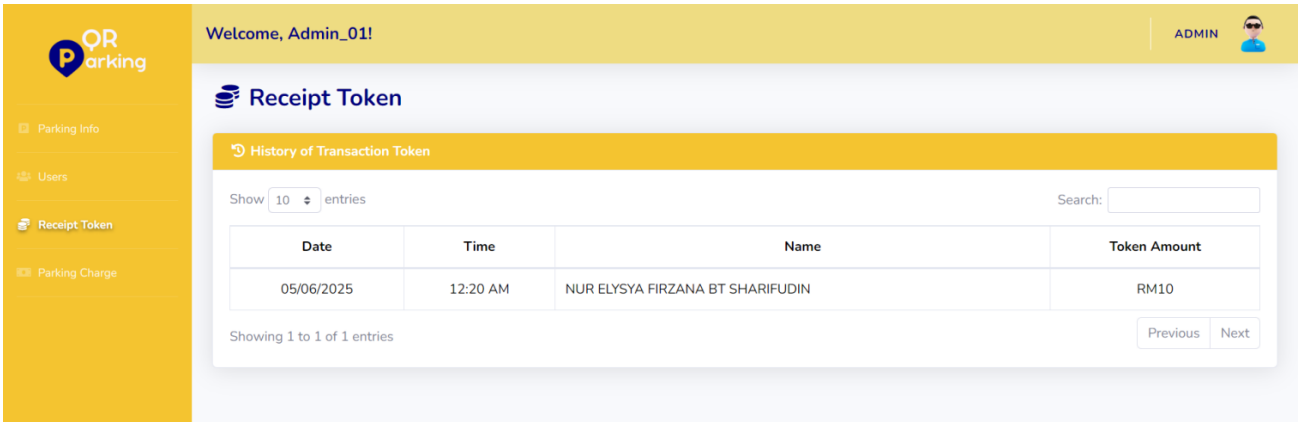


Figure 8: User Top-Up Receipt Token

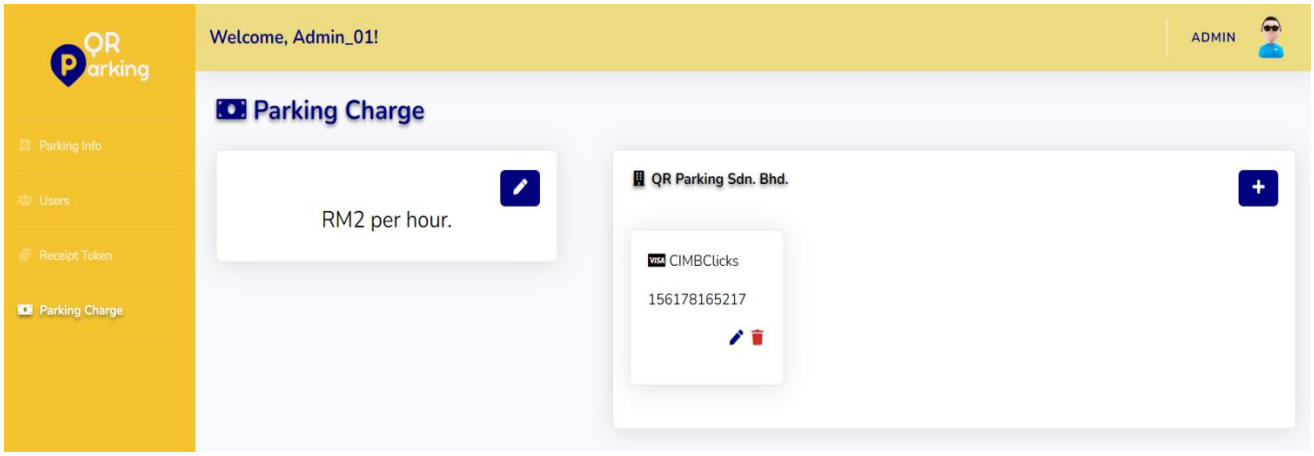


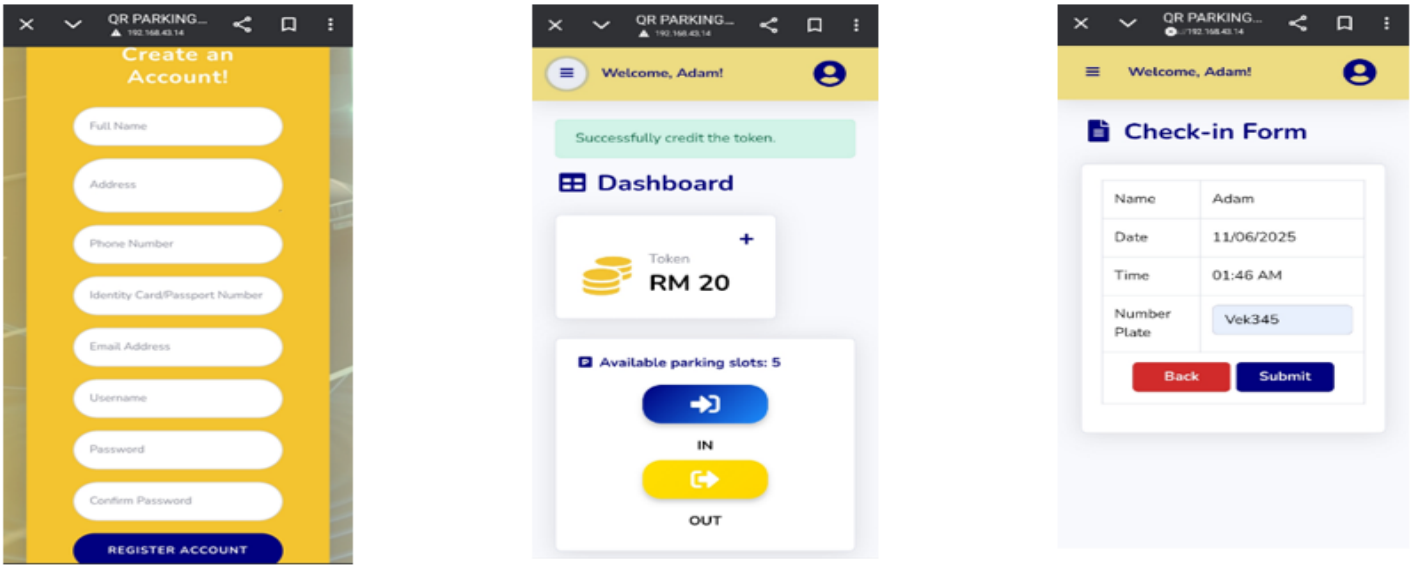
Figure 9: Parking Charge Information

Web Application Interface for Users

Figure 10(a) displays the registration form for new users of the QR Parking System. Users are required to complete the form by entering personal details such as full name, address, phone number, ID number, email, username, and password. Once submitted, the data is stored in the system's database and linked to the user's profile. After successful registration, users can log in through the interface shown in Figure 5 and use the system to scan the QR code at the parking gate. This ensures that only registered users can access the facility, supporting a more secure and organized parking environment. Figure 10(b) shows the user dashboard of the QR Parking System web application. This interface displays the user's remaining token balance (e.g., RM20) used for parking payments and provides real-time updates on parking slot availability. It includes two main

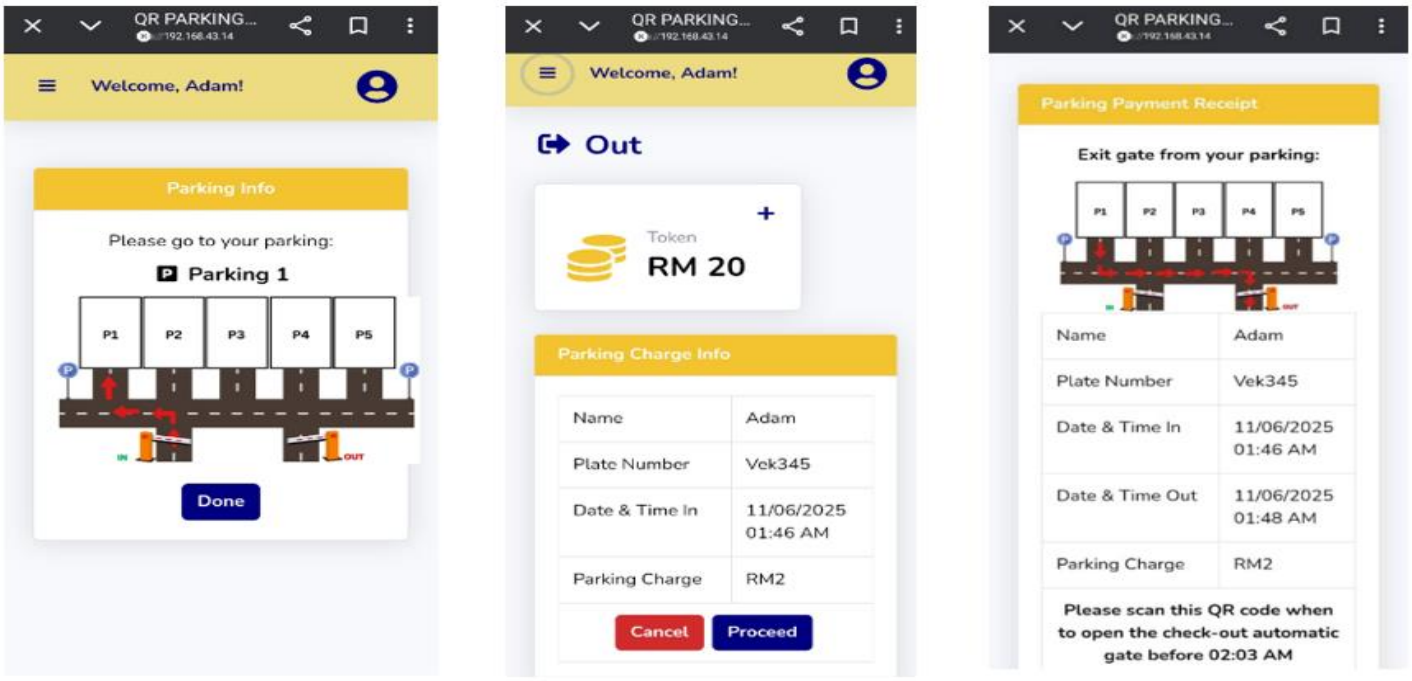
buttons, "IN" and "OUT," guiding the user through the entry or exit process. When the "IN" button is selected, the system activates the device camera to scan the QR code at the entry gate. This scan verifies the user's identity and vehicle details. Upon successful scanning, the system proceeds to the check-in form, as illustrated in Figure 10(c), which records the user's name, entry date and time, and vehicle number.

Next, Figures 11(a),11(b) and 11(c) illustrate the process after a user completes the check-in form in the QR Parking System. As shown in Figure 11(1), the system automatically assigns an available parking slot in real time and displays a visual map to guide the user to their designated space for example, Parking 1 with clear layout and directional arrows. Before exiting, Figure 11(b) shows the system alerts users about the parking charge (RM2 per hour) and checks if their balance is sufficient. If not, users are prompted to top up before continuing. After payment, as shown in Figure 11(c), a visual map guides the user to the exit, and a QR code valid for 15 minutes is generated for gate access. If the user exceeds this time, the QR code becomes invalid and a new payment may be required, ensuring efficient exit flow and better time management.



(a) (b) (c)

Figure 10: (a) Registration Interface (b) Token and Available parking slot (c) Check-in Form



(a) (b) (c)

Figure 11: (a) Visual map Entry Parking (b) Parking Charge Info (c) Visual map Exiting Parking and QR code

Hardware Implementation

The hardware prototype of the QR Code-Based Parking System was successfully tested using real-world conditions. Initially, the system remains idle with all slots empty, as shown in Figure 12, awaiting user action. When a vehicle approaches the entry, the user scans the QR code as shown in Figure 13, and if authentication is successful, the gate opens to allow entry Figure 14. The system then directs the vehicle to an available slot. If the parking lot is full, as illustrated in Figure 15, the system updates the status of all bays and prevents further entry. The hardware components ESP8266 microcontroller, IR sensors, servo motors, buzzer, and LED indicators—work together to manage access and provide real-time feedback. Green and red LEDs indicate whether access is granted or denied, and the buzzer confirms actions such as QR scanning and gate operation. This setup demonstrates effective coordination between hardware and software for smooth parking flow.

Figure 12: Parking Lot is empty

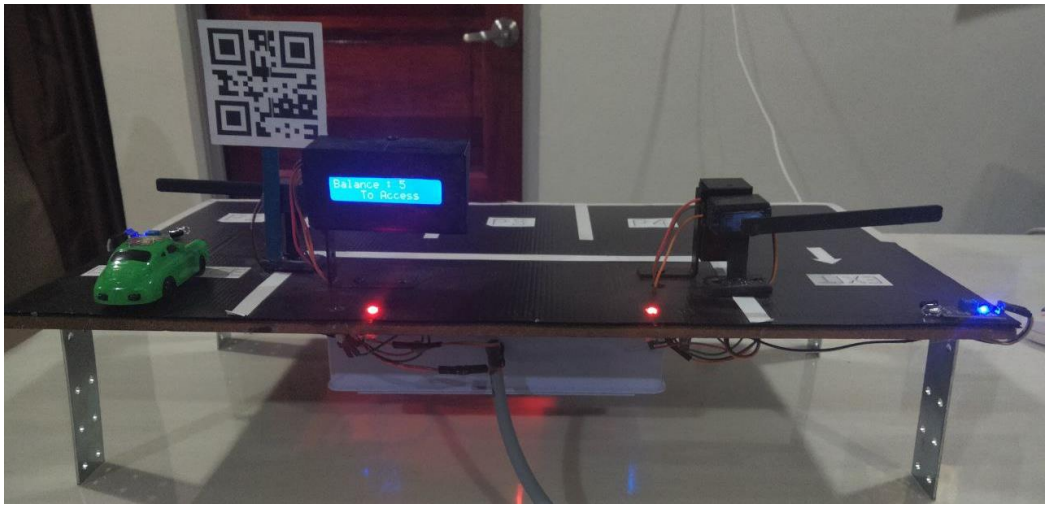


Figure 13: User at the Entrance Before Scanning QR Code

Figure 14: User at the Entrance After Scanning QR Code

Figure 15: Parking Lot is full

Project Analysis by Scenario

In order to examine the efficiency, stability, and the workability of the proposed QR-based electronic parking system, a total of four test scenarios were identified and implemented. All the scenarios represent real-life parking scenarios so that the system can be tested to work properly under normal conditions. These scenarios were uniquely designed to evaluate some of the fundamental features, such as QR code-based authentication on entry, payment validation on exit, security mechanism in case of an unauthenticated access request, and real-time synchronization of parking slot status. The findings of these tests will be instrumental in understanding the overall potential of the system in terms of achievement of secure, efficient and convenient parking experience.

Scenario 1: User Entry

The testing started when a registered user approached the parking entrance. With the web application, the user scanned an eligible QR code at the gate. The system managed to authenticate the code, LCD showed the message Gate Open, green LED and buzzer were turned on and the gate was opened. This process was repeated times under different conditions, confirming that the entry mechanism functions consistently and reliably.

Scenario 2: User Exit

After parking, the user completed the required payment through the web application. When exit, the user scanned a time-sensitive QR Code that was generated by the system. Each time, the system verified the payment, showed a confirmation message, and opened the gate, while accurately updating the parking slot count in the database. This indicated that the system was consistent in managing system exits of users when payment is made within the specified time limits.

Scenario 3: Unauthorized Access Attempt

An unauthorized access attempts; a simulation was carried out in which an unregistered vehicle tried to enter the parking area without completing the registration process. As the web application can only allow registered users to scan the entrance QR Code, the system failed to identify the attempt and denied entrance. No verification was initiated, the gate remained closed, supported by a red LED. This test proved that this system can be dependent upon to identify and bar unauthorized users and hence the safety of the parking facility.

Scenario 4: Real-Time Parking Slot Update

During the testing, successful entry and exit were noted to initiate real-time changes in the available parking slots. The changes made were immediately updated on the user interface and the administrator dashboard, which proved that the database is accurate and synchronized in terms of handling parking availability.

System Reliability Test Results

According to the bar graph as shown in Figure 16, the success rate was 100% in all the four test scenarios, thus indicating that the system is highly reliable. The system was smooth on both entry and exit- registered users could scan in with a valid QR code and the gate opened automatically after payment. It also displayed good security since the system was able to deny access to unregistered vehicles. Finally, the system displayed the number of parking slots in real time without delays. In general, the results demonstrate that this system is precise, safe and functional in the real environment.

Figure 16: Graphical Representation of Results by Scenario

QR Code Reading Performance

To evaluate the system's ability to accurately and efficiently read QR Codes, performance testing was conducted during both entry and exit processes. Each was tested 20 times using valid QR Codes.

Table I shows the analysis of the delay taken during the entry process of 10 test trials with a valid QR Code. The delay is measured from the moment the QR Code is scanned until the gate begins to open. The system had a reliable responsiveness with a delay of between 0.2 seconds and 8.2 seconds. The majority of delays were less than 5 seconds, which means that the system performed well and was fast and reliable when it came to user entry. The delay differs slightly, and this might be due to the user's scanning pattern. In general, the entry process was effective regarding the QR code reading performance.

TABLE I. QR CODE ENTRY SCANNING DELAY TIMES

Process	Testing	Delays
	1	05.4 sec
	2	08.2 sec
	3	03.4 sec

	4	04.3 sec
Entry	5	02.3 sec
	6	07.2 sec
	7	04.4 sec
	8	03.0 sec
	9	01.3 sec
	10	02.2 sec

Table II demonstrates the delay time observed in the exit process when 10 test attempts were made after users made their payment and scanned the exit QR code. The delay time varied between 0.2 seconds and 10.4 seconds with a majority of the results recording less than 7 seconds. There were no failed attempts to enter the system which became consistent in checking payment, showing confirmation messages and activating the gate. This proves the system has the ability to ensure smooth and secure exit flow.

TABLE II. QR CODE EXIT SCANNING DELAY TIMES

Process	**Testing**	**Delays**
	1	04.3 sec
	2	03.4 sec
	3	05.7 sec
	4	04.2 sec
Exit	5	10.4 sec
	6	06.7 sec
	7	09.1 sec
	8	06.6 sec
	9	06.2 sec
	10	05.1 sec

CONCLUSION AND FUTURE WORKS

The Parking System project demonstrates how technology can streamline vehicle access and operation through automation. By using microcontrollers, QR code authentication, and supporting hardware like sensors and servo motors, the system eliminates the need for manual processes and improves user experience. It ensures fast data processing, secure validation, and consistent performance, offering a reliable and efficient solution for managing parking. The integration of real-time data and automated responses helps reduce human error and makes the system suitable for smart applications.

The system achieved a 100% success rate in key functions such as user entry, exit, real-time updates, and prevention of unauthorized access. The QR code scanning process performed effectively with no failures or

long delays. These results confirm that the system is stable and responsive, making it ready for real-world use. With its user-friendly design and dependable performance, this project has strong potential to be implemented in modern urban settings that aim to adopt IoT-based automation. The QR Parking System has strong potential for future upgrades to improve its efficiency and usability. One key enhancement would be installing infrared (IR) sensors at each parking slot to detect real-time availability. This data can be shared directly with both users and administrators through the system interface. With this feature, users will know which spaces are vacant before entering the parking area, helping reduce time spent searching and minimizing congestion.

Another improvement is the integration of voice command features using virtual assistants like Google Assistant, Siri, or Alexa. This would allow users to check slot availability, make reservations, and handle payments through voice control, offering a hands-free, safer, and more convenient experience. These future enhancements align with the latest trends in IoT and smart parking technologies, making the system more accurate, user-friendly, and suitable for real-world applications.

Despite all of its benefits, the smart parking system that uses QR code access has certain drawbacks. The user experience in places with poor connectivity may be hampered by reliance on a reliable internet and suitable devices. Server overload and real-time data updates may be a performance bottleneck on a large scale. In addition, security is a problem. QR codes can be tampered with, and if they are not adequately secured, user information may be compromised. Multi-factor authentication, data encryption, and secure QR code creation should be used to counteract these problems. Load-balancing strategies and cloud architecture can boost scalability. By balancing these factors, the system is made dependable, safe, and prepared for increased use.

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