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Intelligent Parking Management System

Krishna Vishwakarma[1], Ayush Maurya[2], Prateek[3], Prashant Pandey[4], Anil Kumar Chaudhary[5]
[1,2,3,4]*B.Tech 4th year students, Department of Electronics and Communication Engineering,* Dr. A. P. J. Abdul Kalam Technical University, Lucknow, UP, India
[5]*Asst. Prof., Department of Electronics and Communication Engineering, Buddha Institute of Technology, Gorakhpur, UP, India*

Abstract: ***Modern cities receive large numbers of visitors due to the revitalization of cities and the launching of transit services to suburban regions and the bigger mobility of the society. This rise in traffic levels results in large numbers of vehicles on the roads and low parking spaces. This Intelligent Parking Management System (IPMS) helps to develop smart cities as it reduces traffic congestion, reduces human involvement, and optimizes the use of space with automated methods, energy-saving approaches, and logical resource planning. The automatic parking management system runs on an Arduino Mega 2560 microcontroller to automate vehicle entry and exit and slot management. Sensors like IR (or Ultrasonic) detect whether a vehicle is parked in a space which allows the system to provide accurate detection of available spaces, to only open or close entrance and exit gates when a space is available and to avoid traffic congestion caused by an over-capacity in the parking facility. The prototype has parking slots with six standard slots and two EV slots with magnetic induction-based wireless charging capability. The LCD module and the bi-colour LEDs installed in all the slots are used to indicate the parking status in real-time. Green light indicates an available slot and red light indicates an occupied slot. When the parking area is full, a buzzer and an indicator LED will turn on. To prevent excess filling, the entry gate will remain closed. The new model is an efficient solution that is cheap and can be scaled up to reduce manual labour, better use of space and enhanced convenience of the users in the modern parking environments. By monitoring occupancy patterns, controlling gates based on real-time data, and providing the drivers with visual cues like color-coded LEDs, the system allows for faster parking, makes road use more efficient, and contributes to the development of a smart city.***

Keywords: Intelligent Parking, Automated method, Arduino Mega 2560, Visual cues, Real-time monitoring, EV slots with Wireless Charging, Modern Parking System, Smart City.

I. INTRODUCTION

As a result of rapid expansion of urbanization, the number of vehicles has increased steadily, and consequently, parking management appears to represent a major challenge in both cities and other public areas. Current methods of monitoring parking facilities are primarily a manual process and result in either underutilization or overutilization of a parking facility, greater traffic congestion throughout the city, and additional time wasted searching for an available parking space. All of these issues illustrate the need for a smart automated parking management system that can be used to provide real-time information on parking availability and to manage the entry of vehicles into specific parking spaces [1], [7], [10].

The development of intelligent solutions for parking management as a result of improvements to embedded systems and the development of new sensor technologies (e.g., RFID) has led to the creation of smart parking solutions. Smart parking systems use various types of sensors and automated control systems to detect vehicle presence, allocate parking slots, and lead drivers to available parking spaces [2], [3]. The use of smart parking systems will reduce the amount of manual intervention and also increase the efficiency of parking operations and reduce the unnecessary movement of vehicles in parking facilities [6], [10].

The research introduces an Intelligent Parking Management System which uses the Arduino Mega 2560 controller as its control system. The system permits automatic parking spot control together with parking space monitoring through the use of IR and ultrasonic sensors which detect vehicles and bi-colour LED lights that show whether each parking space remains occupied or unoccupied. The prototype contains eight parking spaces which include six standard parking spaces and two magnetic induction charging spaces for electric vehicles [4], [5], [8].

The system controls automatic entry and exit gates through servo motor technology which operates entry and exit processes according to vehicle detection sensors that provide information about empty parking spaces. The system enables drivers to view real-time empty parking space information through the LCD display module which displays both current empty parking spaces and total parked vehicles at that particular moment. Drivers are warned by the system when all parking places are full by using an LED light and a buzzer [6], [9].

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The smart parking system enables organizations to optimize their parking resources while decreasing parking lot traffic and providing users with an automated parking solution that enhances their convenience. The paper shows how modern cities can develop effective smart parking systems through the combination of sensor technology and automated systems which enable real-time system monitoring [7], [10], [11].

II. LITERATURE REVIEW

The worldwide vehicle population increase has created severe difficulties for parking system operation in urban regions. The conventional parking systems need manual operators because they do not provide current parking situation information. Drivers spend excessive time finding parking spots which results in traffic jams and fuel consumption and environmental damage [1], [7], [10]. Researchers have developed smart parking solutions that use embedded systems along with sensors and wireless technologies to solve parking problems [2], [6], [8].

The research field includes multiple studies that investigate automated parking gate systems which depend on microcontroller technology and motorized systems to control vehicle entry and exit. The systems use sensors to identify approaching vehicles which enables them to operate gates through actuators that include servo motors and DC motors. Automated gate control helps reduce human involvement and ensures better traffic flow at parking entrances and exits [4], [6].

The deployment of Internet of Things (IoT) technologies has brought new advancements to smart parking systems throughout the last few years. The IoT-based parking solutions enable drivers to find open parking spots by monitoring parking space availability through mobile applications and web platforms. The systems enable data collection and analysis which supports the optimization of smart city parking infrastructure [3], [8], [9].

The modern parking systems now feature electric vehicle (EV) charging stations as their essential component. Researchers have studied various charging methods for electric vehicles because of their increasing adoption which now includes wireless power transfer through magnetic induction that enables charging without physical connectors [5], [10].

The research review demonstrates that sensor-based parking detection systems combined with automated gate control and real-time monitoring and electric vehicle charging functionality create a system that improves parking operations. The existing systems present two main problems because they either have high costs or complex implementation procedures. The Intelligent Parking Management System developed by the team uses Arduino Mega 2560 to create an affordable prototype that combines its features. The approach presents a workable solution that can grow to meet the requirements of contemporary intelligent parking systems [4], [8], [11].

III. PROBLEM STATEMENT

Parking systems today use manual operations which fail to deliver current parking space status updates. Drivers need to spend excessive time searching for vacant parking spaces which creates traffic delays, fuel consumption, and increased environmental harm [1], [7], [10]. Drivers experience difficulties in identifying vacant spaces because conventional parking systems fail to monitor parking areas and manage their operations automatically [2], [6].

The lack of automated systems for controlling entry and exit operations results in vehicle delays and area overcrowding while requiring human staff to manage the situation. Electric vehicles (EVs) require dedicated parking spaces which should include charging stations as their usage continues to grow. The existing parking infrastructure fails to provide integrated charging solutions which creates operational difficulties for electric vehicle users [5], [10].

Intelligent automated parking management system needs to function as a real-time parking space monitoring system which handles vehicle movements while showing available and occupied parking slots. Parking systems using this technology will achieve better parking results while decreasing traffic congestion and provide superior customer service in parking garages [3], [9], [11].

IV. OBJECTIVES

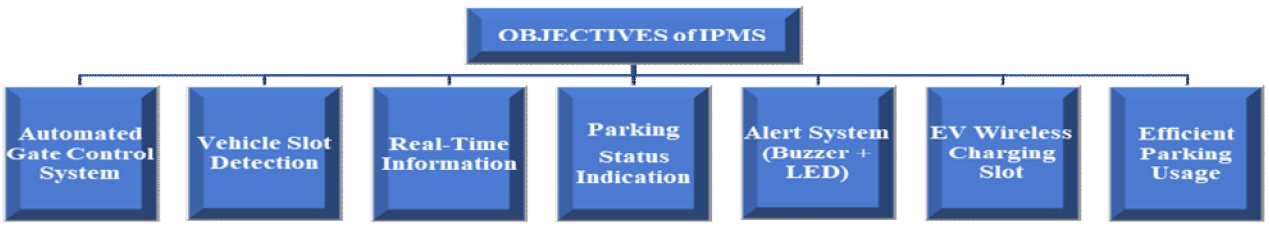


Fig. 1- Chart showing the Objectives of Intelligent Parking Management System (IPMS)

V. SYSTEM ARCHITECTURE

A. *Hardware Components*

TABLE I: Hardware Components Used in the Prototype

S. No.	Hardware Component	Quantity	Description / Function
1	Arduino Mega 2560	1	Primary microcontroller that governs or control the whole parking management system & analyse data from sensors.
2	IR / Ultrasonic Sensors	Multiple (for slots and gates)	Detect the presence of vehicles at the entry/exit gate and in each parking slot.
3	Servo Motors	2	Used to regulate the automatic opening as well as the closure of entry and exit gates.
4	Bi-Colour LEDs (Red/Green)	8	Indicate the status of each parking slot; green for available and red for occupied.
5	LCD Display Module	1	Displays real-time information about available parking slots and total vehicles in the parking area.
6	Buzzer	1	Provides an alert sound when the parking area is full and no slot is available.
7	Indicator LED (Warning LED)	1	Lights up when all parking slots are occupied.
8	Wireless Charging Module (Magnetic Induction)	2	Provides wireless charging facility for electric vehicles in designated EV parking slots.
9	Power Supply Unit	1	Provides required voltage and current to operate the microcontroller and other hardware components.
10	Connecting Wires / Breadboard	As required	Used to connect different electronic components within the system.

B. *Block Diagram*

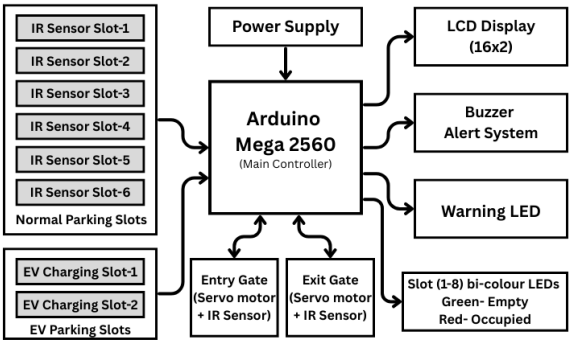


Fig. 2- Block Diagram of Intelligent Parking Management System (IPMS)

VI. SOFTWARE IMPLEMENTATION

The development team created the software design for the Intelligent Parking Management System using both Proteus Design Suite and Arduino Integrated Development Environment (Arduino IDE). The tools enabled to perform circuit simulation and create software program while testing the system before building the physical hardware [4], [8].

The parking management system's complete circuit design and simulation work were performed through Proteus Design Suite. The software enabled users to create virtual circuits that included Arduino Mega 2560 microcontroller, IR sensors, LCD display module, servo motors, LEDs and buzzer and other electronic components. The Proteus simulation system demonstrated that all system elements functioned properly including vehicle detection and parking slot status updates and real-time display changes. This process enabled the detection and rectification of circuit connections and logical errors before the actual system implementation began.

The Arduino Integrated Development Environment was used to create the system control program. The Arduino IDE was used to write the embedded C/C++ code required to process sensor inputs and control LED indicators and operate servo motors for gate control and update the LCD display with real-time parking information. The Arduino Mega 2560 microcontroller received the compiled program after the code was uploaded to it.

The Proteus simulation system became a testing and validation tool for testing which required Arduino programming to prove that the parking management system would function correctly during deployment.

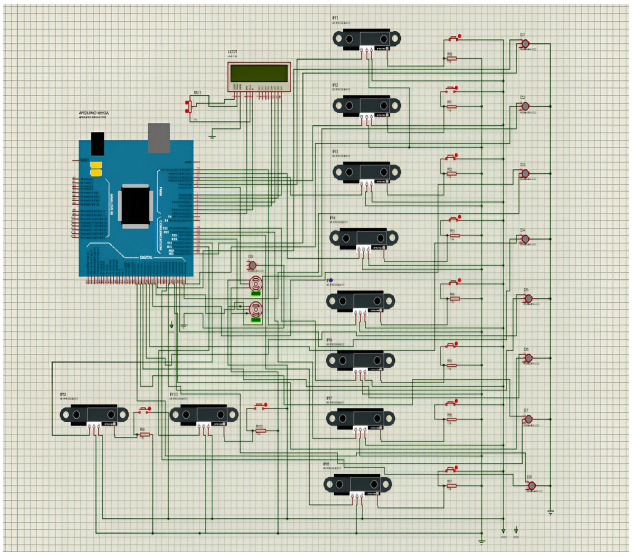


Fig. 3- IPMS Circuit Simulation on Proteus Design Suite

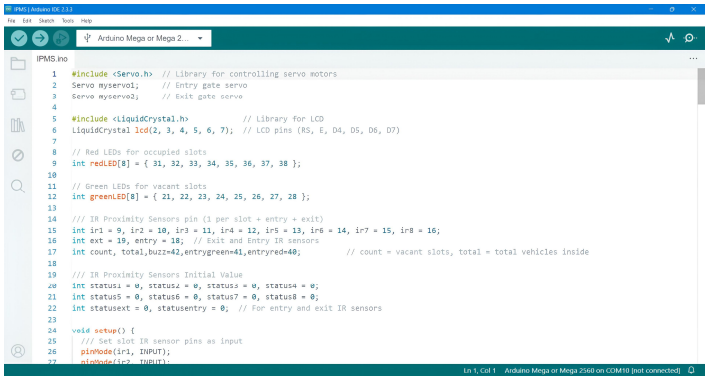


Fig. 4- Source Code of IPMS on Arduino IDE

VII. METHODOLOGY / PROPOSED SOLUTION

1) Based on a sensor-based embedded system driven by the Arduino Mega 2560 microcontroller, the suggested Intelligent Parking Management System is developed. To automatically monitor parking availability and regulate vehicle movement, the system combines sensors, LEDs, servo motors, an LCD screen, and a buzzer. Real-time processing of signals from the sensors by the microcontroller controls the general operation of the parking system [4], [6], [8].

2) The initial phase of the suggested solution emphasizes automated vehicle detection at the entry and exit gates. Detecting approaching cars, infrared or ultrasonic sensors signal the microcontroller. The Arduino triggers the servo motor to open the entrance gate if there is available parking. Likewise, the exit sensor opens the exit gate automatically detects cars leaving the parking lot [4], [6].

3) The parking slot monitoring mechanism makes up the second element. Every parking space features a sensor that identifies a vehicle's presence. These sensors let the system keep current data on available and occupied parking places by constantly sending signals to the controller [2], [8], [9].

4) Utilising bi-colour LEDs, the third section of the system shows visual parking slot indicator. While a red LED signifies that the parking spot is taken, a green LED denotes its availability. This makes it simple for drivers to spot open parking places [6], [9].

5) Real-time parking information display is another major tool. The number of parking spaces available and the overall number of cars in the parking area are shown on a 16x2 LCD module. Sensor information updates the display automatically [4], [8].

6) The parking full alert system is also included in the mechanism. The entrance gate stays shut and a buzzer with an alert LED is turned on to alert drivers that no parking spots are free when all parking places are full [6], [9].

7) The system delivers specialized electric vehicle charging areas which use magnetic induction technology for wireless charging. The parking system enables electric vehicles to charge through wireless technology while their drivers park their vehicles at designated spots [5], [10], [11].

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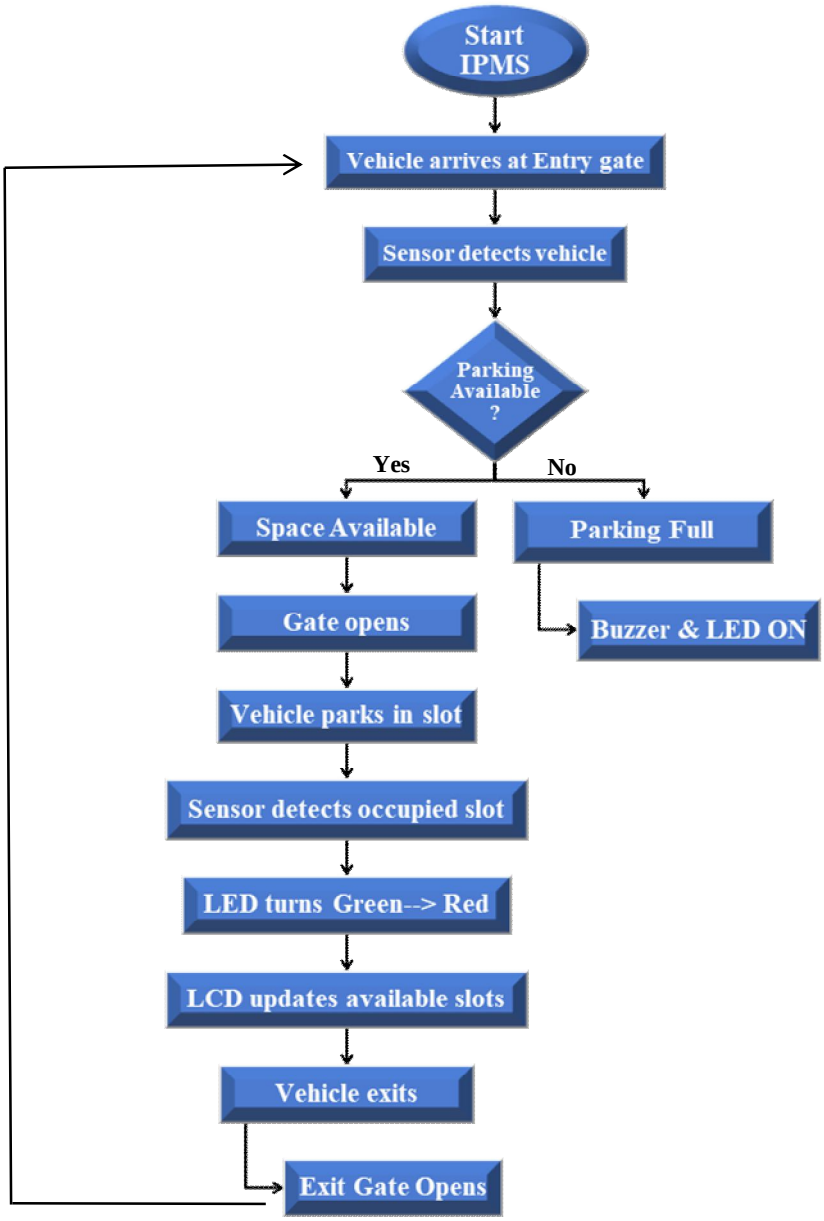


Fig. 5- Process Flow Chart of Intelligent Parking Management System (IPMS)

VIII. EXPERIMENTAL RESULTS

The prototype testing demonstrated both the operational capabilities and the system performance of the Intelligent Parking Management System. The system used an Arduino Mega 2560 microcontroller together with its servo motors and LEDs and various sensors and LCD screen components [4], [6], [8]. The prototype included eight parking spaces of which two spaces served as regular parking while two spaces were set aside for electric vehicle charging [5], [10].

The experimental testing showed that the IR and ultrasonic sensors correctly determined whether vehicles occupied all parking areas [2], [8]. The two-colour LED indicators accurately showed the status of each slot: red for occupied and green for empty [6]. The system's LCD screen displayed two pieces of information which included the total parking lot capacity and the present number of available parking spaces [4], [9].

The automated gate control system functioned successfully. The sensor detected the presence of the car as a vehicle neared the entrance gate and parking space was accessible, then automatically opened the gate by means of the servo motor [4], [6]. The entrance gate remained closed during times when all parking spaces became occupied because the warning LED display and buzzer activated to indicate that no spaces were available [9].

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Given that it can automatically check parking conditions and control gates while concurrently supplying real-time parking status data, the proposed system is proven to be both dependable and effective in the experimental results [1], [7], [10], [11].



Fig. 6- Experimental Status-1 on LCD module



Fig. 7- Experimental Status-2 on LCD module

IX. FEATURES

The proposed Intelligent Parking Management System incorporates several advanced features that improve the efficiency, automation and usability of parking management. The system provides real-time parking availability information while its features minimize the need for human operation [1], [7], [10].

1) Automated Entry and Exit Gate Control System- The system uses servo motor-controlled gates for automatic vehicle entry and exit [4]. The gate system uses sensors to detect approaching vehicles which causes the gate to automatically open and close without needing people to operate it [6], [8].

2) Real-Time Detection of Parking Spaces- The system uses IR and ultrasonic sensors to monitor vehicle presence at each parking slot [2], [8]. The system continually tracks which parking slots are occupied [6], [9].

3) LED-Based Slot Status Indication- Parking slots use bi-colour LEDs to show their current parking space availability status [6]. The green LED shows that a slot is free while the red LED shows that the slot is filled [9].

4) LCD Display for Parking Information- The LCD display module shows current parking space availability along with the total number of vehicles that are parked at the moment [4], [8].

5) Parking Full Alert System- The system uses a buzzer and warning LED to alert drivers about parking space unavailability when all parking slots reach full capacity [6], [9].

6) Dedicated EV Charging Slots- Special parking areas exist in the system which provide electric vehicle drivers with access to wireless magnetic induction charging stations [5], [10].

7) Efficient Parking Space Utilization- The system uses real-time slot data and automated gate operations to decrease traffic jams while optimizing the use of existing parking areas [3], [7], [11].

The proposed system becomes intelligent through these features while it maintains operational efficiency.

X. FUTURE SCOPE

Intelligent automated parking management system needs to function as a real-time parking space monitoring system which handles vehicle movements while showing available and occupied parking. The Intelligent Parking Management System delivers efficient automated parking control its design needs further enhancements and system growth opportunities [1], [7]. The system will enable parking space remote monitoring and access control through mobile applications and web platforms when it adopts Internet of Things (IoT) technology in future developments. The system will enable users to verify parking space availability through live updates before they reach their desired parking space [3], [8], [9].

The system needs a mobile application that enables users to book parking spaces before their arrival which will decrease their wait time and make it an easier and user-friendly system. The system enables parking data storage through cloud databases which allows users to study parking patterns and enhance their parking space management strategies [3], [10].

The parking system expansion will enable commercial businesses to build bigger parking areas which will handle more vehicles through high-tech communication systems and provide more advanced parking management solutions. The parking system will achieve higher efficiency through automatic payment options which include RFID cards QR codes and digital payment systems [2], [9], [11].

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Future system updates will feature AI-based vehicle recognition technology and number plate detection which will strengthen security measures and also help in better vehicle tracking. The system will become more intelligent and scalable through these enhancements which will enable its use in contemporary smart city systems [7], [10], [11].

X. CONCLUSIONS

The research study describes the development and execution of a parking management system which uses sensors and functions using the Arduino Mega 2560 microcontroller. The system uses IR and ultrasonic sensors together with servo motors and bi-colour LED indicators and an LCD display and a buzzer alert system to automate parking operations and provide real-time information about parking availability [4], [6], [8].

The prototype contains eight parking slots which include six standard spaces and two EV spaces that feature wireless charging through magnetic induction. The system uses sensors to detect vehicle presence in each parking space while LEDs show which spaces are occupied. The LCD display shows real-time parking availability and the system uses servo motors to control gates that manage vehicle entry and exit. The system uses a buzzer together with warning LED lights to alert users when the parking area reaches full capacity [5], [6], [9].

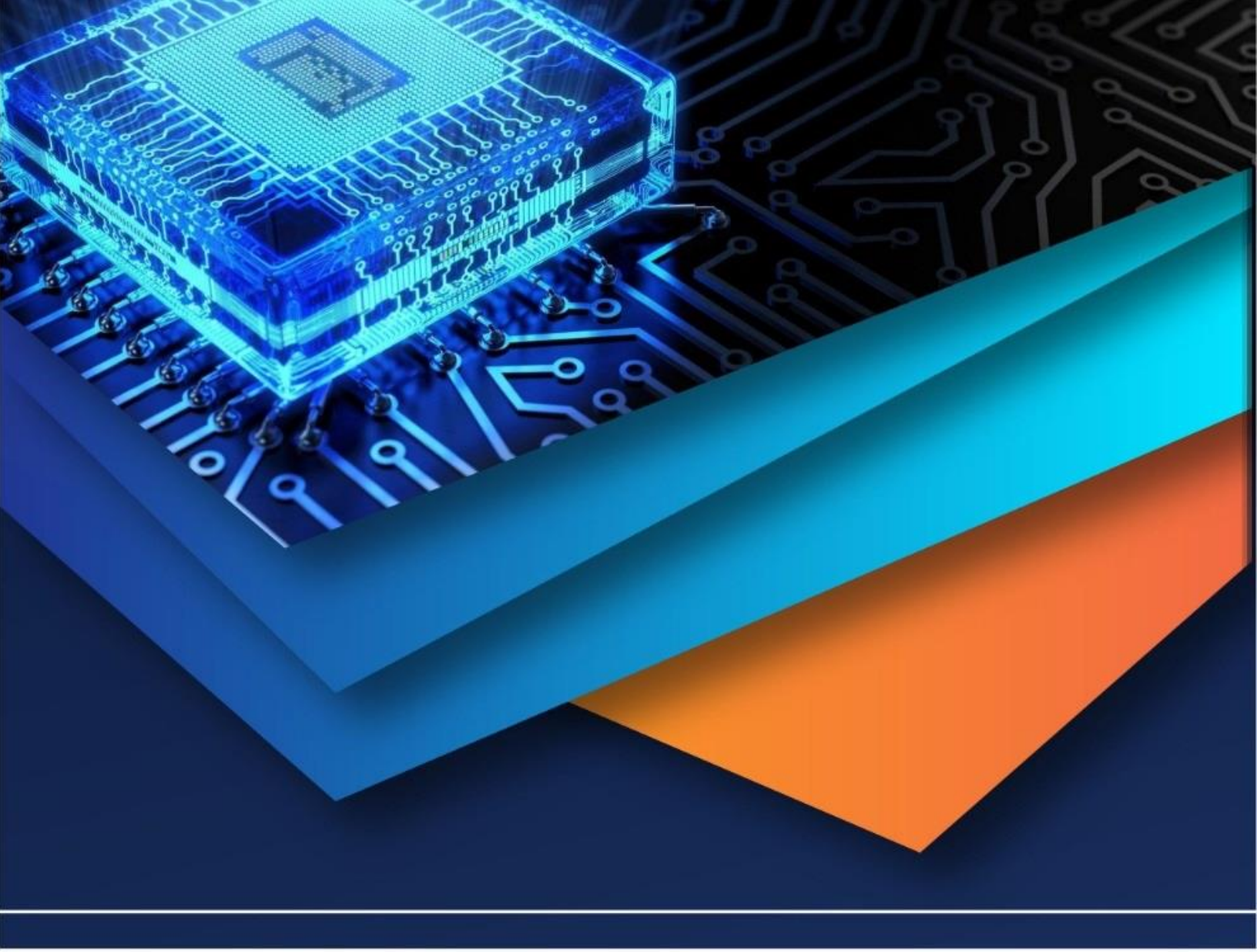
The experimental results show that the system successfully detects parking occupancy while it updates slot information and handles gate operations through automatic control. The system developed in this study increases parking space efficiency and decreases the need for human workers while it improves the effectiveness of parking management which makes it an ideal solution for contemporary smart parking systems [1], [7], [10], [11].

XI. ACKNOWLEDGMENT

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