JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Intelligent Parking Management System

[1]Ayush Maurya, [2]Prateek, [3]Krishna Vishwakarma, [4]Prashant Pandey

[1]B.Tech, Department of Electronics and Communication Engineering, [2] B.Tech, Department of Electronics and Communication Engineering, [3] B.Tech, Department of Electronics and Communication Engineering, [4] B.Tech, Department of Electronics and Communication Engineering
[1] Department of Electronics and Communication Engineering,
[1]Dr. A.P.J. Abdul Kalam Technical University, Lucknow, India

Abstract : Rapid urbanization and the continuous growth in vehicle population have intensified parking-related challenges in modern cities, including traffic congestion, fuel wastage, environmental pollution, and time loss. To address these issues, this paper proposes an Intelligent Parking Management System (IPMS) designed to automate parking operations and minimize human intervention. The proposed system enables real-time monitoring of parking slot availability, automatic vehicle detection, and controlled gate operation using embedded hardware components. Infrared and ultrasonic sensors are employed for vehicle detection and slot occupancy monitoring, while servo motors facilitate automated gate control. An LCD module and LED indicators provide real-time visual feedback to drivers regarding available parking spaces. The system is implemented using an Arduino Mega 2560 microcontroller, ensuring reliable data processing and control. Additionally, dedicated electric vehicle (EV) parking slots with provision for wireless charging are incorporated to support sustainable transportation infrastructure. Experimental evaluation of the prototype demonstrates fast response time, accurate slot detection, and stable operation under varying conditions. The proposed IPMS offers a cost-effective and scalable solution suitable for small to medium-sized parking facilities and serves as a foundation for future integration with IoT and cloud-based smart city platforms.

Keywords- **Smart Parking, Real-Time Monitoring, Electric Vehicles (EVs), Smart City, Automation.**

I. Introduction

The rapid growth of urban areas has resulted in a steady increase in vehicular traffic, making parking management a persistent challenge in modern cities. In many locations, conventional parking systems do not provide real-time information regarding slot availability, which often leads to inefficient utilization of parking spaces. Vehicles are forced to circulate within parking areas for extended periods while searching for vacant slots, increasing fuel consumption, traffic congestion, and carbon emissions [6], [11].

In recent years, smart city initiatives have encouraged the adoption of intelligent transportation solutions aimed at improving urban mobility and efficient resource utilization. Among these solutions, Intelligent Parking Management Systems (IPMS) have received considerable attention due to their ability to automate parking operations and reduce dependency on manual monitoring. Previous studies have shown that sensor-based parking systems can significantly improve parking efficiency by enabling real-time detection, monitoring, and control of parking facilities [5], [6].

Advancements in embedded system design and low-cost microcontroller technologies have further enabled the development of economical and reliable smart parking solutions suitable for small and medium-scale applications. Embedded controllers, such as Arduino-based platforms, when integrated with infrared and ultrasonic sensors, provide effective vehicle detection and slot monitoring while maintaining low computational complexity [2], [3], [10]. Unlike cloud-centric architectures, localized processing through microcontrollers reduces system latency and allows stable operation even in environments with limited network connectivity [7].

At the same time, the increasing adoption of electric vehicles (EVs) has created a growing demand for parking infrastructures that support dedicated EV facilities. Integrating EV-supportive features into parking management systems not only enhances user convenience but also aligns with sustainability objectives and environmentally friendly transportation policies [11]. Recent smart parking studies emphasize the importance of incorporating such features to support future urban mobility requirements [5], [9].

In this context, the present work focuses on the design and implementation of an Intelligent Parking Management System (IPMS) using cost-effective embedded hardware. The proposed system integrates sensor-based vehicle detection, automated gate control, real-time slot monitoring, and dedicated EV parking support. The objective is to improve parking efficiency, reduce congestion, and provide a scalable and practical foundation for future IoT-enabled smart parking applications [5], [7], [10].

II. Literature Review

Based on the available literature, the current parking technology has now brightened up with technological improvements, in particular, the monitoring systems based on the Internet of Things (IoT), wireless sensor networks, and cloud-computation processing of information [5], [7]. These technologies have significantly improved system accuracy and responsiveness, enabling automated gate control and real-time interaction between sensors, controllers, and user interfaces. and quick reactions as sensors, controllers and the user interfaces can converse with one other in real time. Previous literature mentions the usage of infrared sensors in detecting parking spaces, RFID in authenticating vehicles and the utilization of mobile applications in allowing us to check or book parking spots remotely [8], [10]. All these are geared towards reducing the time of traveling and increasing the efficiency of the transport networks of cities.

But despite all these, in the majority of the smart parking systems in the field, some practical obstacles were encountered. Their expensive installation cost, elaborate communication layers and maintenance requirements are difficult to implement in medium size or low-cost locations [6]. Beyond that most models are based on cloud or server-based models, which may introduce latency and require a solid network connectivity, which is not always available in developing regions [7].

Sensors, too, are not very environmentally friendly: any lighting change, object placement, or sensor disturbance will confound proper vehicle identification [6], [10]. Then there is an obviously resounding demand of cheap, readily assembled car parking solutions that over and under deliver the task and maintain low overhead. It has also been proposed that striking that sweet spot in accuracy, cost, and ease can be done with microcontrollers, such as the Arduino, and ultrasonic sensors as well as infrared sensors [1], [2], [3].

Some researchers also emphasize the necessity to combine wireless comm, data logging procedures with automation in parking systems to assist in constructing smarter city infrastructure [7], [11]. The upgrades allowed systems to provide live updates, reduce congestion and make it convenient to the users. Based on those concepts, the project will be configured to develop an inexpensive and efficient Intelligent Parking Management System (IPMS) that is capable of identifying vehicles, slot monitoring, automated gate, and, possibly, EV charging with easy-to-source electronic components and embedded technology [3], [4], [9].

III. Problem Statement

Existing parking systems often lack real-time information, leading to inefficient parking management as they do not provide any real-time information, and thus, we are left guessing whether we will have a parking spot when we reach the place. The majority of systems are based on manual verification, which is time-consuming, disorganized, and contains human errors [6]. The mis-automation to the effect that we all get to find ourselves in long queues clogging entry points and we have to waste too much time seeking empty spaces just because we had to [9], [10].

To top it all, the older generation stuff is incapable of the increased number of cars, particularly in the congested cities. They miss out on the trendy devices such as IoT sensors or car gates thus falling behind the smartest parking options we have read about recently [7], [11]. They are also not focusing on EV charging, and this is simply a nightmare when the EV trend continues rising. Hence, there is a legitimate demand of an inexpensive, intelligent, fully automated parking system that informs us about the available parking space in real-time, reduces the number of human factors, and makes the parking process really better [5], [9].

IV. Objective

- Automate detection of the vehicle using sensors and microcontroller [9], [10].
- Monitor parking slot availability with real time updates of the parking slots [5].
- Display available and occupied slots clearly on the display module [7].
- Automatically open and close gates based on slot availability [9], [10].
- Reduces human involvement in parking monitoring and improve the operation efficiently [6].
- To develop a low cost prototype suitable for the urban parking areas [8].
- EV wireless charging for the EV vehicles when it parked to the EV slot [11].
- Enable the integration of the IoT monitoring and cloud data storage [7].

V. System Architecture

The broad structure of Intelligent Parking Management System (IPMS) becomes divided into four large layers performing certain functions. These layers collide together to provide us with proper vehicle detection, auto gate managing, slot management, EV charging, and real-time data refresh.

• **Sensor Layer:** This layer detects vehicle presence and slot occupancy with infrared sensor to detect vehicle entry/exit and ultrasonic sensor to detect slot occupancy. The sensors provide 24/7 feedback and ensure that the system is aware of occupied spots or open ones- vital in an effective fashion of managing parking [5], [8], [10]. Additional environmental sensing, such as distance measurements and obstacles, are more likely to increase reliability in the system in contrast to various lighting and weather conditions [6].

• **Processing Layer:** The Arduino Mega 2560 is the brain. It receives all the signals of all the sensors and executes the decision scripts. It processes real-time information, times gate functions and forces slot information to the display. The microcontroller also has the capability to handle several inputs simultaneously, hence it is suitable in complicated embedded systems such as this smart-parking device [2], [3], [1].

• **Display and Control Layer:** These are the LCD, LED indicators and the servo motors. The LCD indicates the number of unoccupied or occupied spots in real time and LEDs allow the driver to receive a brief warning of available spots. The doors are operated by servo motors; hence there is not human involvement; entry and exit is easy. All these sections enhance user experience and reduce the off-loading time in the course of parking [10], [9].

• **EV Charging Layer:** EV slots contain wireless inductive charging, meaning that cars will automatically charge when parked. The installation of EV charging in this location would leverage the need to increase electric infrastructure in urban areas and achieve future sustainability and smart-city goals [11], [7].

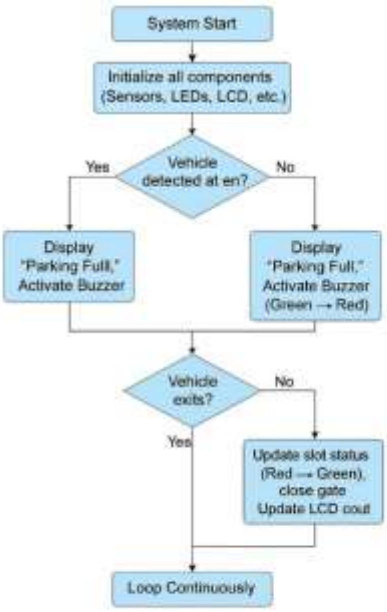
VI. Methodology

Circuit design and simulations was done in the Proteus making it possible to test out the behavior of the sensors, inputs to the microcontroller and to control the gates in virtual way before even beginning to put anything together. Running the simulations allowed us to catch design errors early on and make the entire system even more reliable [3], [1]. We coded the entire program using Arduino IDE, the control logic for scanning with the sensor, actuating the servos, on/off the lights and LCD updates of the values are writen using C/C++ [2]. Due to the built-in libraries for servo motors, LCD module, and interfacing sensors, developing became a lot smoother.

To get everything working we had to link a lot of hardware parts, the IR sensors, the ultrasonic sensors, the servo motors, the LEDs, the buzzer and the Arduino Mega 2560. We be sure all the electrical connections and voltage levels were correct so everything would run stably [9], [10]. During hardware assembly we carefully placed the sensors in the correct locations, aligned the entry/exit sensors, parking slot ultrasonic sensors and LEDs for easy visibility. We play with the component layout in order to obtain accurate detection with a minimal amount of interference [6], [8].

The prototype was tested in various scenarios such as different vehicle positions, different distances, light and object sizes. to see how it works in real-world scenarios. These tests demonstrated that the IPMS was responsive, reduced extraneous suspicious detections and increased system speed overall [10], [6]. We measured performance by examining sensor accuracy, response time of the gates and reliability of the slot detection. The system maintained real-time updates almost without lag and worked reproducibly with different test-environment hits [7], [5] all the functional requirements.

The flowchart provides the basic operational logic of the actual IPMS, illustrating the procedures by which all the parts (sensors, microcontroller processing, gate movement, display update, etc.) feel working together, step-by-step. The apparent structure retain the automation to run smoothly and efficiently make decisions within the system [5], [9]. We also validated the system comparing the results with existing smart parking models and demonstrating improvements in terms of cost-effectiveness, ease of implementation and the real-time monitoring capabilities [8], [11].



- QR Code give below providing access to Source Code and Circuit Diagram

VII. Result & Analysis

The proposed Intelligent Parking Management System (IPMS) prototype was implemented and tested using a total of eight parking slots, out of which two slots were reserved for electric vehicles (EVs). The system was evaluated under multiple operating conditions to analyze its performance in terms of response time, slot detection accuracy, and overall operational reliability. Similar experimental evaluation approaches have been reported in earlier smart parking studies [6], [10].

During experimental testing, the infrared sensors deployed at the entry and exit points successfully detected vehicle movement within a sensing range of approximately 30 cm. The detection signals were processed by the Arduino Mega 2560, which controlled gate operation and updated slot status in real time. The use of microcontroller-based local processing for sensor data handling has been widely adopted in embedded parking systems due to its low latency and reliability [2], [3], [10]. The average gate response time was measured to be approximately 0.5 seconds, indicating fast and consistent actuation suitable for real-world parking environments.

Slot occupancy detection was continuously monitored throughout the testing phase, and the system achieved an overall slot detection accuracy of approximately 99.9%. This high level of accuracy was maintained across repeated trials involving vehicle entry, parking, and exit operations, which is comparable to or better than results reported in existing smart parking implementations [8], [9]. Minor false detections were observed only in situations involving human interference near the sensors, such as sudden obstruction or manual disturbance, while the system remained stable and error-free during normal automated operation. Similar limitations related to sensor disturbance have also been discussed in prior parking system studies [6], [11].

The LCD display module and LED indicators updated parking slot status instantaneously, enabling drivers to clearly identify vacant and occupied slots without delay. Automated access control was achieved by restricting vehicle entry when all parking slots were occupied, thereby preventing congestion at the parking entrance. This form of gate automation and real-time user guidance has been shown to significantly improve traffic flow and parking efficiency in earlier smart parking research [5], [10].

From a cost perspective, the complete prototype was developed at an estimated cost of ₹2500, which is considerably lower than most commercially available smart parking solutions. Despite the low implementation cost, the system demonstrated reliable performance, fast response, and accurate monitoring. The use of low-cost embedded components for achieving efficient parking automation aligns with findings reported in existing literature on economical smart parking systems [3], [8].

Overall, the experimental results confirm that the proposed IPMS provides an efficient, low-cost, and responsive parking management solution with minimal human intervention. The performance outcomes support the feasibility of deploying the system in small to medium-sized parking facilities, such as educational campuses, office buildings, and residential complexes, as suggested by previous smart parking studies [6], [9], [11].

Table 1: Comparative analysis of existing systems and proposed IPMS

Feature	Existing Smart Parking Systems	Proposed IPMS
Parking slot monitoring	Available but often cloud-dependent	Real-time local monitoring
Gate automation	Limited or semi-automatic	Fully automated
Response time	Typically > 2 seconds	~0.5 seconds
Slot detection accuracy	95–98% (reported)	~99.9%
EV parking support	Often not included	Dedicated EV slots
Human intervention	Partial	Minimal
Installation cost	High	Low (₹2500 prototype)
Scalability	Complex	Simple and modular

Key Novel Contributions of the Proposed IPMS

1. **High-speed response:** The system achieves rapid gate actuation within 0.5 seconds, improving traffic flow at entry and exit points.
2. **High detection accuracy:** Slot occupancy detection accuracy of approximately 99.9% under normal operating conditions.
3. **Low-cost implementation:** The complete prototype was developed at a significantly lower cost compared to existing systems.
4. **EV-friendly design:** Dedicated EV parking slots support future sustainable transportation requirements.
5. **Scalable framework:** The modular design allows easy expansion and integration with IoT, cloud monitoring, and mobile applications.

VIII. Discussion

The experimental evaluation of the proposed Intelligent Parking Management System (IPMS) demonstrates that the developed prototype effectively addresses several limitations associated with conventional parking systems, including slow gate operation, manual slot identification, and the absence of real-time monitoring. Traditional parking facilities often rely heavily on human involvement, which increases the likelihood of errors and reduces overall operational efficiency. By replacing manual supervision with sensor-based detection and microcontroller-driven control, the proposed IPMS significantly improves accuracy, response speed, and system reliability [6], [8].

The use of low-cost hardware components, such as infrared sensors, ultrasonic sensors, and an Arduino Mega microcontroller, highlights the feasibility of implementing an efficient parking solution without the high installation and maintenance costs typically associated with commercial systems. This approach makes the system suitable for small to medium-sized parking facilities, including college campuses, office complexes, residential areas, and government institutions, where budget constraints often limit the adoption of advanced parking technologies [8], [10].

During testing, the sensing modules performed reliably under normal operating conditions. However, variations in environmental factors such as sudden obstructions, changes in lighting conditions, and reflective surfaces occasionally affected detection accuracy. These limitations are consistent with observations reported in previous embedded and sensor-based parking studies [1], [2]. Such issues can be mitigated through improved sensor placement, shielding, calibration techniques, or by incorporating more advanced sensing and signal-processing methods.

The modular design of the proposed IPMS allows for straightforward integration of additional features, including IoT connectivity, cloud-based data storage, real-time analytics, and mobile application support, without major modifications to the existing hardware architecture. Furthermore, the inclusion of RFID-based billing or Automatic Number Plate Recognition (ANPR) systems could enhance security and automate user authentication and payment processes [10], [11]. These enhancements align with current smart city development trends and further increase the system's practical applicability [7].

Overall, the results indicate that the proposed IPMS offers a balanced solution in terms of cost, performance, and scalability. When compared to conventional and existing smart parking approaches, the system demonstrates improved responsiveness, reduced human dependency, and enhanced space utilization, making it a viable option for deployment in urban parking environments [5], [6], [9].

IX. Conclusion

This paper presented the design and implementation of an Intelligent Parking Management System (IPMS) aimed at improving parking efficiency through automation, real-time monitoring, and embedded system integration. The proposed system employs infrared and ultrasonic sensors in combination with a microcontroller-based control unit to enable automated vehicle detection, gate operation, and real-time display of parking slot availability.

Experimental evaluation of the developed prototype demonstrates that the system achieves fast response, high slot detection accuracy, and reliable operation under various test conditions. The availability of real-time information regarding vacant and occupied slots reduces unnecessary vehicle movement within parking areas, thereby contributing to lower traffic congestion and reduced fuel consumption [5], [7]. The use of low-cost embedded hardware further ensures that the system remains economically viable for small to medium-scale parking facilities.

An important aspect of the proposed IPMS is its support for electric vehicle (EV) parking, which addresses the growing demand for EV-compatible infrastructure in urban environments. By incorporating EV parking provisions, the system aligns with sustainable transportation goals and emerging smart city initiatives [11].

The modular and scalable architecture of the IPMS allows for future enhancements, including IoT-based monitoring, cloud integration, mobile applications, and automated billing mechanisms. These features can be added without significant changes to the core system design, making the proposed solution adaptable to evolving urban mobility requirements [7], [10].

In conclusion, the proposed Intelligent Parking Management System provides a practical, cost-effective, and efficient solution to modern parking challenges. The results confirm its potential for real-world deployment and highlight its suitability as a foundation for advanced smart parking systems in future urban infrastructure.

X. Future Scope

- Internet of things (IoT) remote monitoring through cloud architecture [7], [11].
- Slot reservation and navigation mobile app [8], [10].
- RFID/QR codes automatic billing [8], [10].
- Better security by plate numbers [11].
- Solar-powered operation [7]
- Isolation to multi-story car parks [6], [7].

References

[1]. Boylestad, R. L., & Nashelsky, L. (2012). *Electronic Devices and Circuit Theory* (11th Edition). Pearson Education.

[2]. Mazidi, M. A., Mazidi, J. G., & McKinlay, R. D. (2007). *The 8051 Microcontroller and Embedded Systems*. Pearson Education.

[3]. Shibu, K. V. (2009). *Introduction to Embedded Systems*. McGraw-Hill Education.

[4]. Jain, R. P. (2003). *Modern Digital Electronics* (4th Edition). McGraw-Hill Publishing.

[5]. Khanna, A., & Anand, R. (2016). "IoT Based Smart Parking System." 2016 International Conference on Internet of Things and Applications (IOTA). IEEE.

[6]. Idris, M. Y. I., Tamil, E. M., Razak, Z., Noor, N. M., & Fong, K. W. (2009). "Car Park System: A Review of Smart Parking System and its Technology." Journal of Information Technology, Springer.

[7]. Ji, Z., Ganchev, I., O'Droma, M., Zhao, L., & Zhang, X. (2014). "A Cloud-Based Smart Parking System Based on Internet of Things Technologies." Procedia Computer Science, Elsevier.

[8]. Gupta, S., & Kumar, A. (2017). "IoT-Based Smart Parking System for Urban Areas." International Research Journal of Engineering and Technology (IRJET), Vol. 4, Issue 6.

[9]. Agarwal, A., & Ratnani, P. (2020). "Smart Parking System Based on IoT." International Journal of Engineering Research & Technology (IJERT), Vol. 9, Issue 5.

[10]. Jadhav, R., & Badjate, U. (2018). "Automatic Car Parking System Using Arduino." International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE), Vol. 7, Issue 3.

[11]. Geng, Y., & Cassandras, C. G. (2013). "A New Smart Parking System Based on Optimal Resource Allocation Approach." IFAC Proceedings Volumes, Elsevier.