Libyan Open University Journal of Applied Sciences (LOUJAS)
Volume 2 - Issue 2 - 2026 - Pages 47-61

Smart IoT-Based Multi-Level Parking System with a Real-Time Guidance Mechanism

Ahmed Salem Daw Alarga [1*], Haytham Abdulmajid Almuzoughi [2], Elhadi Elfitory Algarai [3], Yousef A. A. Hammad [4], Abdussalam Ali Ahmed [5]
[1,2] Department of Electrical and Electronic Engineering, Faculty of Engineering-Algarabolli, Elmergib University, AlKhums, Libya
[3] Software Engineering Department, Elmergib University, Khums, Libya
[4] Higher Institute of Science and Technology, Tarhuna, Libya
[5] Mechanical Engineering Department, Bani Waleed University, Libya
[*] **Email for reference researcher**: ahmedar82.as@gmail.com

نظام مواقف سيارات ذكي متعدد الطوابق قائم على إنترنت الأشياء مزود بآلية توجيه في الوقت الفعلي

أحمد سالم الارقع [1*]، هيثم عبد المجيد المزوغي [2]، الهادي الفيتوري الجراي [3]، يوسف حماد [4]، عبد السلام علي أحمد [5]
[1،2] قسم الهندسة الكهربائية والحاسوب، كلية الهندسة-القرة بوللي، جامعة المرقب، الخمس، ليبيا
[3] قسم هندسة البرمجيات، كلية تقنية المعلومات، جامعة المرقب، الخمس، ليبيا
[4] قسم الهندسة الكهربائية، المعهد العالي للعلوم والتقنية - ترهونة، ترهونة، ليبيا
[5] قسم الهندسة الميكانيكية والصناعية، الهندسة، بني وليد، بني وليد، ليبيا

Received: 02-06-2026; Accepted: 05-07-2026; Published: 09-07-2026

Abstract:
The development of smart parking systems is a significant topic that has attracted considerable attention from researchers due to their important role in reducing traffic congestion, thereby minimizing environmental pollution, saving drivers' time and effort, and contributing to improved economic efficiency. This research aims to design and implement a smart parking system featuring a vertical expansion mechanism with multiple levels. Movement between these levels is achieved using an electric elevator, based on the priority of available parking spaces starting from the lower floor. In addition, the system provides a simple user interface that enables users to remotely identify available parking spaces within the facility. This paper presents a model of a multi-story smart parking system based on the Internet of Things (IoT) using an ESP32-S3 development board. Available parking spaces on different levels are detected using LDR sensors, and drivers are then guided to the appropriate space via an LCD display located at the parking entrance. Movement between floors is carried out using an electric elevator that is automatically controlled through a set of infrared sensors (IR) placed inside and outside the elevator. The elevator gate is opened to access the upper floor only when the lower floor is fully occupied and a free space is available on the upper floor. The use of two different types of sensors represents a key aspect of the proposed system, as it achieves a balance between the high performance and reliability of IR sensors and the low cost of LDR sensors. In addition, a web-based interface has been developed to display real-time parking information, allowing drivers to remotely check the availability of parking spaces before arriving at the parking area. The system testing results demonstrated an overall accuracy of approximately 93%, highlighting the effectiveness of sensor diversity in achieving a balanced trade-off between performance and cost. This makes the proposed system both efficient and economically viable.

Keywords: Multi-Level Parking, IoT, LDR Sensor, IR Sensor, Web page.

الملخص
يُعدّ تطوير أنظمة المواقف الذكية من المواضيع المهمة التي حظيت باهتمامٍ كبير من الباحثين، نظرًا لما تؤديه هذه الأنظمة من دورٍ بارز في الحد من الازدحام المروري، مما يسهم في تقليل التلوث البيئي، وتوفير وقت وجهد السائقين، فضلًا عن تحسين الكفاءة الاقتصادية. يهدف هذا البحث إلى تصميم وتنفيذ نظام مواقف سيارات ذكي يتميز بآلية توسع رأسي متعددة الطوابق، حيث يتم التنقل بين الطوابق باستخدام مصعد كهربائي وفقًا لأولوية توفر أماكن الوقوف، بدءًا من الطابق السفلي. بالإضافة إلى ذلك، يوفر النظام واجهة مستخدم بسيطة تُمكّن المستخدمين من التعرف على أماكن الوقوف الشاغرة داخل الموقف عن بُعد. تُقدّم هذه الورقة نموذجًا لموقف سيارات ذكي متعدد الطوابق قائم على إنترنت الأشياء IoT باستخدام لوحة التطوير ESP32-S3 ويتم الكشف عن أماكن الوقوف الشاغرة في الطوابق المختلفة باستخدام مستشعرات LDR، ثم يُوجَّه السائق إلى المكان المناسب عبر شاشة عرض LCD مثبتة عند مدخل الموقف. ويتم الانتقال بين الطوابق باستخدام مصعد كهربائي يُتحكم فيه أوتوماتيكيًا من خلال مجموعة من مستشعرات الأشعة تحت الحمراء IR المثبتة داخل المصعد وخارجه، بحيث لا تُفتح بوابة المصعد للانتقال إلى الطابق العلوي إلا عند امتلاء الطابق السفلي بالكامل وتوفر مكان شاغر في الطابق العلوي. ويُعد استخدام نوعين مختلفين من المستشعرات أحد الجوانب الأساسية في النظام المقترح، إذ يحقق توازنًا بين الأداء العالي والموثوقية التي تتميز بها مستشعرات IR، والتكلفة المنخفضة التي تتميز بها مستشعرات LDR الإضافة إلى ذلك، تم تطوير واجهة ويب لعرض معلومات الموقف في الوقت الفعلي، مما يتيح للسائقين التحقق عن بُعد من توفر أماكن الوقوف قبل الوصول إلى الموقف. وأظهرت نتائج اختبار النظام تحقيق دقة إجمالية بلغت نحو **93%**، مما يؤكد فاعلية تنوع المستشعرات في تحقيق توازن مناسب بين الأداء والتكلفة. ويجعل ذلك النظام المقترح يتميز بكفاءة تشغيلية عالية وجدوى اقتصادية مناسبة.

الكلمات المفتاحية: موقف متعدد الطوابق، انترنت الأشياء، حساس LDR، حساسIR، صفحة ويب.

i.Introduction

Recently, traffic congestion has increased significantly due to the rapid growth in the number of vehicles on the roads. This has posed a major challenge to the efficiency of parking systems in general, and traditional parking systems in particular [1,2,3]. Studies indicate that approximately 30% of traffic congestion is caused by drivers searching for a suitable parking space [2,4]. Traditional parking systems rely mainly on manual searching by drivers to find an available space, which involves repeatedly circulating within the parking area. This process can be time-consuming and contributes to increased traffic congestion [3,5]. Some studies also report that the number of vehicles in the United States alone increases annually by approximately 248,000 vehicles. This has led to significant challenges related to insufficient parking availability, in addition to environmental pollution and the waste of energy and resources [3]. The main cause of these issues is attributed to the repeated search for available parking spaces, resulting from drivers' inability to quickly and easily identify suitable spaces [6]. Smart parking systems have helped address many of the problems associated with traditional systems, such as wasted time and effort, traffic congestion, and the resulting increase in environmental pollution. In addition, these systems provide extra services such as parking monitoring, advance reservation, and improved space utilization within urban areas [1,2,3,4,7]. Studies have shown that the time required to find an available parking space ranges from 3.5 to 14 minutes, which further aggravates congestion and pollution problems, as well as wasting drivers' time [2,7].

One of the key advantages of smart parking systems is their positive impact on driver behavior. A study reported a reduction in parking violations when such systems are implemented [7]. The Internet of Things (IoT) is an integrated system of electronic components, including sensors, communication modules, processing units, and actuators, which communicate with each other communication networks, enabling remote monitoring and control [9,10]. This technology has led to a significant transformation across many fields, converting traditional systems into intelligent systems capable of real-time data exchange, thereby facilitating monitoring and control processes [11]. Consequently, rapid advancements have been achieved in various sectors such as smart cities, industry, agriculture, and healthcare [12]. The Internet of Things (IoT) has emerged as an effective solution to traffic congestion by improving parking management and providing users with useful information such as available spaces, advance reservation options, user identification, and driver guidance to appropriate parking locations

[1,3,6]. In smart parking systems, sensors are utilized for multiple functions, including detecting available parking spaces, identifying vehicles at entry gates, and recognizing vehicles and drivers. The collected data is transmitted to processing units to manage and control the parking system, representing a key application of IoT [2,3]. Based on the above, smart parking systems based on modern technologies such as the Internet of Things and artificial intelligence can significantly contribute to solving the problems associated with traditional parking systems and improving their efficiency [2].

ii.Related Work

Parking systems have evolved over several decades, starting from traditional systems operated entirely by humans, then progressing to semi-automated systems managed by both humans and machines, and finally reaching fully automated smart parking systems. These systems can be classified into three main levels: manual parking systems operated by human labor; semi-automated systems that rely on human intervention using machines; and fully automated smart parking systems, which are capable of detecting available spaces, guiding drivers, and controlling gate operations without human intervention [2,3]. With technological advancements, parking systems have undergone a significant transformation, particularly with the emergence of the Internet of Things (IoT) and artificial intelligence (AI), leading to the development of many modern system designs [2]. IoT is considered one of the key technologies driving this evolution, as it relies on the integration of sensors, communication modules, and processing units to enable real-time monitoring and control [5]. The Internet of Things has significantly contributed to the development of smart parking systems by enabling efficient data collection and analysis. This has helped reduce fuel consumption and time, while also easing the burden on drivers searching for available parking spaces [13,14]. In addition, Wireless Sensor Networks (WSNs) have been widely used to collect data from parking areas and transmit it to control units through gateways [2]. Various technologies have been applied in smart parking systems, including expert systems, fuzzy logic, Global Positioning System (GPS), and computer vision, all of which have contributed to improving parking management efficiency [3]. Artificial intelligence techniques have also played an important role in the development of these systems. Machine learning algorithms and image processing methods are used to analyze parking data and identify vehicles through real-time camera systems, enabling features such as advance reservation and improved parking management [2,18]. On the other hand, technologies such as Radio Frequency Identification (RFID) are used for vehicle identification. In this approach, vehicles are equipped with identification tags that are read wirelessly upon entry. Despite its effectiveness, this technology faces challenges such as signal interference and sensitivity to physical obstacles [3,15]. Fuzzy logic has also been utilized in the design of multi-layered smart parking systems, which typically include sensing, network, processing, and application layers. These systems support data analysis and decision-making; however, they may suffer from complexity and challenges in practical implementation [16,17]. Different types of sensors are used in smart parking systems, such as LDR sensors, inductive sensors, magnetic sensors, ultrasonic sensors, and infrared (IR) sensors [3]. While these sensors enhance data acquisition, each type has its own limitations, such as sensitivity of optical sensors to lighting conditions, ultrasonic sensors to noise, and magnetic sensors to surrounding electromagnetic fields. In terms of practical implementations, several IoT-based smart parking models have been developed. One example utilizes an Arduino board combined with IR sensors and RFID technology for vehicle detection and access control, with data displayed through an internet-connected platform [1]. Machine learning techniques have also been applied to develop advanced systems for license plate recognition and the management of entry and exit processes. However, such systems often require high computational resources, which increases their overall cost [4,19]. Other studies have incorporated advanced communication technologies such as LoRa to improve connectivity within parking environments, along with the use of multiple sensors to enhance detection accuracy [20]. The impact of smart parking systems on

Libyan Open University Journal of Applied Sciences (LOUJAS)
Volume 2 - Issue 2 - 2026 - Pages 47-61

user behavior has also been investigated. Results indicate that these systems help reduce traffic violations caused by improper parking and improve compliance with traffic regulations [7]. Based on the above, it is evident that the advancement of smart parking systems relies on the integration of multiple technologies, including IoT, artificial intelligence, and sensing systems, which collectively contribute to improving parking management efficiency and reducing associated challenges. Despite the extensive research conducted on smart parking systems, which has significantly contributed to improving their development and efficiency, limited attention has been given to remote and rural areas [1]. Furthermore, the technologies employed in smart parking system design face several challenges, particularly environmental factors that can significantly affect the performance of sensors and cameras. This highlights the need for selecting and developing sensors capable of operating reliably under various environmental conditions. In addition, communication and connectivity between sensors, processing units, and control units play a critical role in improving system efficiency. However, these communication mechanisms may encounter challenges caused by physical obstacles, which can lead to signal interference and degradation [2]. On the other hand, existing parking systems still lack effective mechanisms for efficient data management and real-time updating [4]. Moreover, vertical expansion approaches in parking design, through the development of multi-story parking facilities to reduce land consumption, have not received sufficient attention in most previous studies and system designs. This paper presents a model of an IoT-based multi-story smart parking system using an ESP32-S3 development board, integrating different types of sensors that provide a balance between low cost and accurate detection performance.

iii.System Overview

A set of LDR sensors was installed within the designated parking spaces across different levels of the parking facility to detect the presence of vehicles. In addition, IR sensors, characterized by their fast response and high reliability, were employed to detect vehicles at the parking entrance gate, the elevator gate, and inside the elevator to monitor vehicle entry and exit operations. These locations require immediate system responses to ensure efficient operation. The system prioritizes guiding drivers to available parking spaces, starting from the ground level and then progressing to higher levels. Drivers are directed to upper levels only when the lower level is fully occupied. This guidance process is provided through an LCD display, in addition to a web interface that presents comprehensive information about the parking status. To achieve higher space utilization efficiency, an elevator-based mechanism was adopted for vertical transportation between parking levels. The system is controlled by an ESP32 development board, which receives and processes sensor signals, displays the obtained information on the LCD screen and web interface, and transmits appropriate control signals to the actuators, including gate motors and the elevator motor.

iv.System Architecture

Smart Parking Systems (SPS) mainly consist of several essential components, including sensors responsible for data acquisition, communication networks that enable connectivity between system components such as Wi-Fi, ZigBee, and cellular networks, data processing units responsible for data analysis and decision-making, user interfaces such as web pages and mobile applications, and actuators such as gate motors [2,20]. In this research, a multi-story smart parking model was designed and implemented, as illustrated in Figure 1, based on three main components:

Libyan Open University Journal of Applied Sciences (LOUJAS)
Volume 2 - Issue 2 - 2026 - Pages 47-61

Figure 1. illustrates the proposed parking model presented in this research.

v.Mechanical Part:

As shown in Figure 2, the mechanical part represents the physical structure used to construct the parking model. It mainly consists of the parking base, the lower level, the upper level, and the elevator.

Figure 2. illustrates the mechanical structure of the proposed parking model.

vi.Software Part:

The software part includes the programs developed to implement the system control algorithms which is Arduino ID, in addition to the design of a web interface for remotely displaying parking information. A web page was developed to display the real-time status of the parking system, as shown in Figure 3. Users can access this information from anywhere through the Internet, allowing them to check parking availability remotely without the need to manually search for available spaces.

Figure 3. indicates the web page used to display parking system

vii.Electronic Part:

The electronic part consists of a set of electronic components interconnected as illustrated in Figure 4. These components were integrated to construct and operate the proposed parking model.

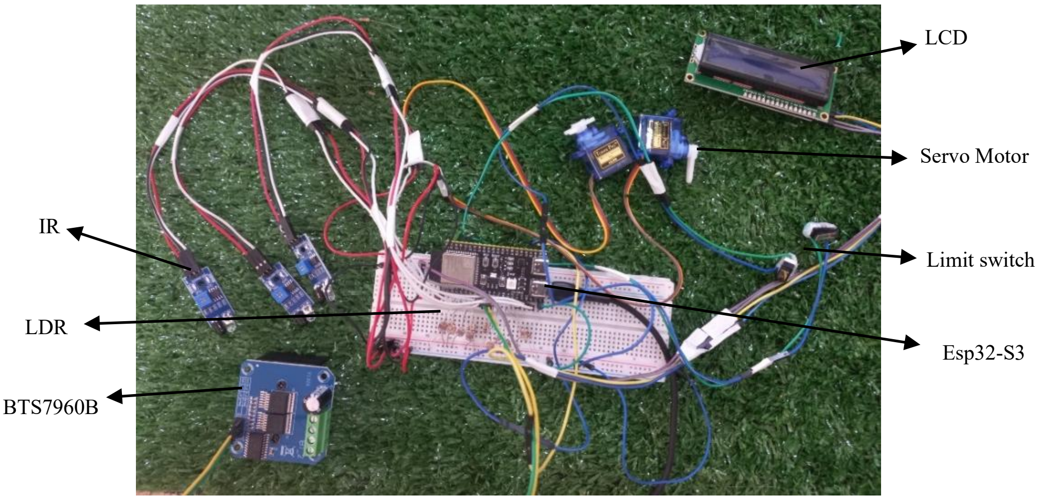

Figure 4. illustrates the electronic components of the parking model and their interconnections

viii.ESP32-S3 Board

The ESP32-S3 development board shown in figure 5, serves as the main processing unit of the system. It receives signals from various components, including sensors (LDR and IR) and limit switches, processes the collected data, and generates appropriate control commands for actuators such as servo motors and the DC motor. In addition, the board supports wireless Wi-Fi communication, enabling remote monitoring and control of the system through a web interface.

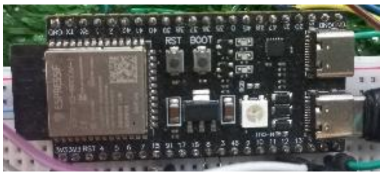

Figure 5. shows the ESP32-S3 development board

ix.IR and LDR Sensors

Two different types of sensors which LDR shown in figure 6-a, and IR sensor shown in figure 6-a, were utilized to achieve a balance between system cost and performance. LDR sensors were selected due to their low cost and acceptable detection capability and were installed in the designated parking spaces. On the other hand, IR sensors, which provide higher accuracy and faster response, were employed in locations requiring immediate detection, such as the parking entrance gate, elevator gate, and inside the elevator.

Figure 6-a. shows IR sensor

Figure 6-b. shows LDR sensor

Libyan Open University Journal of Applied Sciences (LOUJAS)
Volume 2 - Issue 2 - 2026 - Pages 47-61

- **Servo Motor SG90**

The servo motor is one of the most important actuators used in miniature engineering models. It is characterized by its ability to achieve precise angular position control, making it an ideal choice for controlling entrance and exit gates in smart parking applications. In this research, the SG90 servo motor, shown in Figure 7, was used to control the opening and closing of the main parking gate and the elevator gate.

Figure 7. shows the SG90 servo motor

x.Actuators (Elevator System)

A DC motor, shown in Figure 8, was used to move the elevator vertically between parking levels. A threaded shaft was connected to the motor rotor, where the rotational motion of the motor is converted into vertical movement of the elevator through the rotation of the threaded shaft.

Figure 8. shows the DC motor

xi.DC Motor Driver

A DC motor driver circuit, such as the BTS7960B, is an essential electronic component used to control the speed and direction of DC motors using Pulse Width Modulation (PWM). It provides a high current capacity (up to 43 A in some versions), allowing efficient motor operation while protecting the system components from excessive current and overheating. Figure 9 illustrates the motor driver circuit used in this research.

Figure 9. shows the BTS7960B DC motor driver circuit

Libyan Open University Journal of Applied Sciences (LOUJAS)
Volume 2 - Issue 2 - 2026 - Pages 47-61

xii.Limit Switch

Two limit switches, as shown in Figure 10, were used in the elevator system. The first limit switch was installed at the lower elevator base and sends a signal to the ESP32 board when the elevator reaches the lowest position. The second limit switch was installed at the upper elevator base and sends a signal to the ESP32 board when the elevator reaches the highest position.

Figure 10. shows the limit switch.

xiii.LCD Display

The LCD display shown in Figure 11 is used to guide drivers to the appropriate parking place. It enables the driver to identify whether available spaces exist within the parking facility and provides directions to the suitable parking space through the display, even when an Internet connection is unavailable.

Figure 11. shown used LCD to guide drivers to the appropriate parking place

xiv.Block Diagram

The block diagram shown in Figure 12 illustrates the architecture of the proposed parking system. It demonstrates the data flow from the sensors to the ESP32-S3 board, where the collected data is processed. Based on the processing results, appropriate control signals are generated and transmitted to the actuators. In addition, the system information is displayed through a web interface.

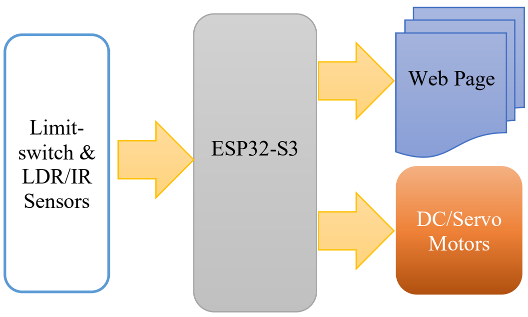

Figure 12. illustrates the system architecture of the proposed M-SPS

xv.System Concept

The proposed multi-story smart parking system based on the Internet of Things (IoT) relies on the ESP32-S3 development board as the main processing unit. The board collects data from a set of sensors distributed across the parking slots, processes the received information, and generates control commands for the actuators, including the DC motor and servo motors. The processed information is also displayed through an LCD screen and a web interface. LDR sensors are used to detect the occupancy status of parking slots on different levels by monitoring changes in light intensity. In contrast, IR sensors are utilized in locations that require fast response and reliable detection, such as detecting vehicles at the parking entrance gate, elevator gates, and inside the elevator during vehicle entry and exit operations. The proposed system follows a priority-based parking allocation strategy, where drivers are guided to available spaces starting from the lower level. Access to upper levels is allowed only when the lower level becomes fully occupied. This guidance is provided through both the LCD display and the web interface, which provides updated information about the parking status. An elevator mechanism is also integrated to enable efficient movement between different parking levels.

xvi.System Design and Implementation

A. Parking Slot Detection

Two types of sensors, LDR and IR sensors, are employed in the proposed smart parking system to achieve a balance between cost and detection performance.

LDR sensors are installed within the designated parking slots to detect occupancy status by measuring variations in light intensity. When a vehicle occupies a parking slot, the amount of light received by the sensor decreases, causing a change in the output voltage. The parking slot status (available or occupied) is then determined by comparing the measured value with a predefined threshold.

On the other hand, IR sensors are used in locations requiring rapid response and higher detection reliability, including the parking entrance gate, the lower and upper elevator gates, and inside the elevator cabin. These sensors operate based on infrared reflection principles to detect the presence of vehicles instantly.

B. Multi-Level Parking Control

The operating algorithm of the proposed system consists of three main stages:

1. Detection

The detection stage includes monitoring all parking slots within the parking facility, in addition to detecting vehicle presence at the entrance gate and elevator access points.

2. Monitoring and Display

The parking status is continuously displayed in real time through the web interface, allowing drivers to remotely check available and occupied spaces. An LCD screen is also used to provide local guidance for drivers inside the parking facility.

3. Priority Logic

The system prioritizes the allocation of parking spaces on the lower level. When all spaces on the lower level are occupied, the system automatically directs the driver to the upper level and activates the elevator system.

C. Elevator Control System

The elevator control system is based on IR sensors and limit switches to ensure accurate operation. The elevator gate opens when a vehicle assigned to the upper level is detected in front of the elevator gate. After the vehicle enters the elevator and its position is confirmed using the internal IR sensor, the DC motor is activated to move the elevator vertically.

To achieve accurate positioning at each level, limit switches are installed at predefined locations. These switches provide feedback to the ESP32-S3 board when the elevator reaches the upper or lower position during upward and downward movement.

D. Web Monitoring System

A web-based monitoring interface was developed to display real-time parking information. The interface provides the current status of available and occupied parking slots, allowing drivers to remotely monitor parking availability. The ESP32-S3 operates as a web server and updates the displayed information continuously through the wireless network.

E. Offline Guidance System

To ensure system availability during Internet connection failures, a local guidance system was implemented using an LCD screen installed at the parking entrance. The display provides drivers with information about parking availability and guides them toward suitable parking locations without requiring Internet access.

xvii.Results and Discussion

The proposed smart parking model was implemented and tested under several parking occupancy scenarios. Figure 13 illustrates the numbering scheme adopted for the two parking levels. The parking slots on the lower level were assigned the labels (L1, L2, L3, and L4), while the upper-level parking slots were assigned the labels (U1, U2, U3, and U4).

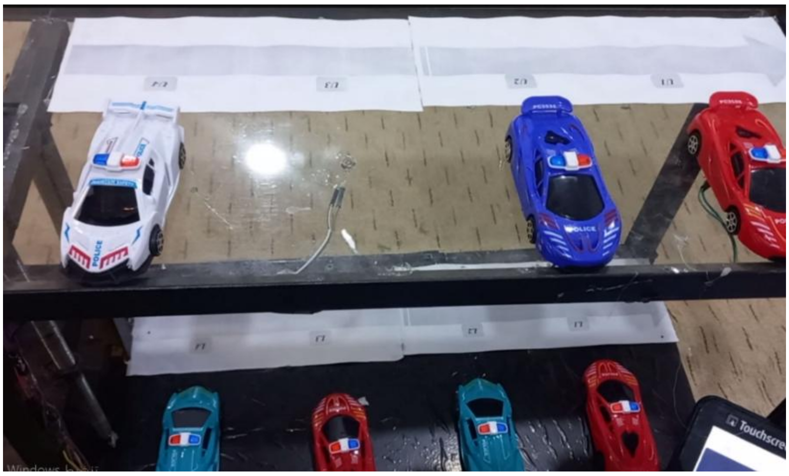

Figure 13. illustrates the numbering scheme adopted for the two parking levels.

The first scenario represents the case of complete parking occupancy, where no available parking slots exist, as shown in Figure 14. The same condition is displayed on the web interface shown in figure 15, which reflects the overall occupancy status of the parking system. All parking slots are shown as occupied, and the statistical indicator (Free 0/8) represents the number of available slots compared with the total parking capacity.

Figure 14. Parking System with No Available Parking Slots.

Figure 15. Web Page When No Parking Spaces Are Available.

In Figure 16, the occupancy status changes, where the available parking slots are (L3, U1, U2, and U3), while the occupied slots are (L1, L2, L4, and U4). This information is displayed in real time through the web interface, as illustrated in Figure 17. The interface indicates that four out of eight parking slots are available (Free 4/8).

Figure 16. Parking System with Available Parking slots.

Figure 17. Web Page with Available Parking slots.

Similarly, Figure 18 presents another parking occupancy scenario containing a combination of vacant and occupied slots with a different distribution pattern. This scenario was also displayed through the web interface as illustrated in figure 19, confirming the capability of the proposed system to provide accurate and reliable real-time occupancy monitoring.

Figure 18. Parking System under Different Parking Availability Conditions

Figure 19. Web Page with Different Parking Availability Conditions

The driver guidance scenario, illustrated in Figure 20, demonstrates the ability of the system to direct the driver to parking slot L3 on the lower level. This scenario verifies the effectiveness of the adopted allocation algorithm, which is based on the priority of available parking spaces. Furthermore, it highlights the importance of the LCD display in providing direct guidance to drivers even when Internet connectivity is unavailable.

Figure 20. Driver guidance to an available parking slots L3 on lower level

Furthermore, another driver guidance scenario for the upper level was tested, where the system directed the driver to parking slot U2, as shown in Figure 21. In this case, the elevator system was automatically activated due to the absence of available spaces on the lower level. The activation process is demonstrated by opening the elevator gate, as shown in Figure 22.

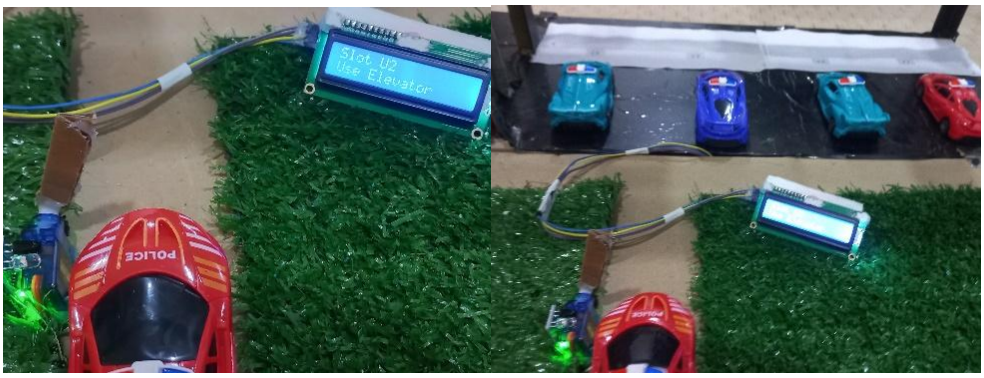

Figure 20. **Figure 21:** Driver guidance to an available parking slots L3 on upper level

Figure 22. Elevator gate opening scenario

The obtained results demonstrate the effectiveness of the proposed system in identifying parking slot occupancy status using LDR sensors. In addition, the system showed reliable performance in detecting vehicle presence at the gates and inside the elevator using infrared IR sensors. The system also achieved efficient driver guidance according to the implemented priority algorithm, where vehicles are directed to lower-level spaces first and then to upper levels when the lower level becomes fully occupied. Moreover, the elevator control system demonstrated stable and efficient operation in transporting vehicles between different levels, with high positioning accuracy at predefined locations through the integration of IR sensors and limit switches. The performance of the proposed system was evaluated by calculating the accuracy of each subsystem based on the test samples presented in Table (1). The LDR sensors used for parking slot detection achieved an accuracy of approximately 83%, while the IR sensors used at the elevator entrances and inside the elevator achieved a higher accuracy of approximately 95%. The elevator control system, which integrates IR sensors and limit switches, achieved an operational accuracy of approximately 93%.

$$Accuracy(\%) = \frac{Correct\ detections}{Total\ tests} * 100$$

Table 1: System Performance Evaluation

Subsystem	Sensor Type	Total Tests	Correct Detections	Accuracy (%)	Response Time
Parking Slots	LDR	30	25	83%	~1.5 sec
Entry Gates	IR	20	19	95%	~0.5 sec
Elevator System	IR & Limit Switch	15	14	93%	~1 sec

The overall system accuracy was computed as a weighted average based on the number of tests for each subsystem:

$$System\ Accuracy = \frac{(0.83 * 30) + (0.95 * 20) + (0.93 * 15)}{65} = 88.3\%$$

This confirms the effectiveness of the proposed system in practical applications.

Conclusion

Based on the experimental results obtained from the IoT-based multi-story parking model, the proposed system demonstrates a high level of applicability in real-world scenarios. It has proven its capability to efficiently manage parking spaces and enhance occupancy monitoring, while addressing common challenges associated with traditional parking systems, such as difficulty in locating available spaces, traffic congestion caused by searching for parking, and the absence of real-time parking information. The results further indicate that the integration of low-cost and high-performance sensors provides an effective balance between economic feasibility and system accuracy, thereby improving the overall reliability and adaptability of the system across different operating environments. The system successfully achieved real-time occupancy updates through a web-based interface, in addition to providing direct driver guidance via an LCD display. This significantly enhances user experience and reduces the time required to locate available parking spaces. Moreover, the proposed system demonstrated robust performance in both online and offline modes. The availability of a local guidance mechanism based on an LCD display ensures continuous system operation even in the absence of Internet connectivity, thereby increasing system reliability and operational flexibility. Overall, the findings confirm that the proposed system offers a cost-effective and efficient solution for smart parking management compared to conventional and commercial systems. Furthermore, it provides a scalable and flexible foundation for future developments, such as integration with mobile applications and artificial intelligence techniques, which can further optimize parking management and contribute to the advancement of smart city infrastructures.

References

1. N. S et al., ISPS: RFID Powered IoT Based Smart Parking System, 2024 International Conference on Communication, Computing, Smart Materials and Devices (ICCCSMD), Chennai, India, 2024, pp. 1-6.
2. Sai Sneha Channamallu, Sharareh Kermanshachi, Jay Michael Rosenberger, Apurva Pamidimukkala, Smart parking systems: A comprehensive review of digitalization of parking services, Green Energy and Intelligent Transportation, Volume 5, Issue 1, 2026, 100293, ISSN 2773-1537.
3. M. R. Alam, S. Saha, M. B. Bostami, M. S. Islam, M. S. Aadeeb and A. K. M. M. Islam, A Survey on IoT Driven Smart Parking Management System: Approaches, Limitations and Future Research Agenda, in IEEE Access, vol. 11, pp. 119523-119543, 2023.
4. Aswath S., Kishore N., S.K. Thinagaran, Vishwaa M., Hariharan A., Vasavi C.S., B. Karthikeyan, Smart Car Parking System with Online Reservation, Procedia Computer Science, Volume 258, 2025, Pages 2777-2786, ISSN 1877-0509.
5. Atusa Javaheri, Sai Sneha Channamallu, Sharareh Kermanshachi, Jay Michael Rosenberger, Apurva Pamidimukkala, Chen Kan, Greg Hladik, Predictive analysis of parking behavior after implementation of smart parking system, Transportation Research Procedia, Volume 90, 2025,Pages 871-878, ISSN 2352-1465
6. Miskolczi, Márk, Melinda Jászberényi, and Dávid Tóth. 2021. Technology-Enhanced Airport Services— Attractiveness from the Travelers' Perspective. Sustainability (Switzerland) 13(2):1–18.
7. Kumar, Suresh, Irfanullah Khan, Danish, Alveena Aslam, and Muhammad Imran Majid. 2022. Internet of Things Based Transducer Application to Harness Tidal Energy from Coastal and Offshore Pakistan. Sukkur IBA Journal of Emerging Technologies 5(1):78–89.
8. Abdul Ghaffar Khoso, Noufil Zahid, Irfanullah Khan, Enhanced IoT-Enabled Smart Parking system with RFID Integration and Line Assistance, Transportation Research Procedia, Volume 84, 2025,Pages 346-353, ISSN 2352-1465,
9. Hao Wang, Sai Sneha Channamallu, Apurva Pamidimukkala, Sharareh Kermanshachi, Jay Michael Rosenberger, Chen Kan, Greg Hladik, Economics of smart parking: predictive analytics in optimizing urban parking revenue, Transportation Research Procedia, Volume 90, 2025, Pages 879-886, ISSN 2352-1465,
10. H. Zulfiqar, H. M. Ul Haque, F. Tariq, and R. M. Khan, A survey on smart parking systems in urban cities, Concurrency Comput., Pract. Exper., vol. 35, no. 15, Jul. 2023, Art. no. e6511.
11. Charles, Joel, Aniket Dhage, Gayatri Bodele, Trupti Bargat, and Jyotsna Gawai. 2022. RFID Based Smart Parking System Using Firebase. International Journal of Research in Engineering, Science and Management 5(2):31–33.
12. M. A. Shroud, M. Eame, E. Elsaghayer, A. Almabrouk, and Y. Nassar, Challenges and opportunities in smart parking sensor technologies, Int. J. Electr. Eng. Sustainability (IJEES), vol. 1, pp. 44–59, Jul. 2023.
13. M. Faiz and A. K. Daniel, A multi-criteria cloud selection model based on fuzzy logic technique for QoS, Int. J. Syst. Assurance Eng. Manage., vol. 13, pp. 1–18, Oct. 2022.

14. Sutjarittham, T., Gharakheili, H. H., Kanhere, S. S., & Sivaraman, V., 2022. Monetizing Parking IoT Data via Demand Prediction and Optimal Space Sharing. IEEE Internet of Things Journal, 9(8, 5629–5644.
15. Allah Ditta, Muhammad Maroof Ahmed, Tehseen Mazhar, Tariq Shahzad, Yazan Alahmed, Habib Hamam, Number plate recognition smart parking management system using IoT, Measurement: Sensors, Volume 37, 2025, 101409, ISSN 2665-9174,
16. Waheb A. Jabbar, Lu Yi Tiew, Nadiah Y. Ali Shah, Internet of things enabled parking management system using long range wide area network for smart city, Internet of Things and Cyber-Physical Systems, Volume 4, 2024, Pages 82-98, ISSN 2667-3452,