

IOT BASED SMART PARKING SYSTEM

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Abstract:

Rapid urbanization and the surge in vehicle ownership have exacerbated parking challenges, leading to congestion, pollution, and time loss. This paper proposes an Internet of Things (IoT)-based Smart Parking System (SPS) for real-time parking space monitoring and management. The system integrates sensors, an LCD display, a keypad, a servomotor, and a centralized control unit. Sensors detect the occupancy status of each slot and transmit the data wirelessly to the control unit, which processes and displays available spaces on the LCD for efficient driver guidance. A keypad-based access mechanism restricts entry to reserved zones for staff and VIP members. The proposed SPS delivers accurate, real-time availability information, reducing search time, traffic congestion, fuel consumption, and emissions. It also enforces parking rules by identifying unauthorized or overstaying vehicles, records parking duration, and streamlines entry operations. Experimental results demonstrate that the system improves parking efficiency, enhances user experience, and supports sustainable urban mobility.

Keywords: Smart Parking System, Internet of Things (IoT), real-time monitoring, urban mobility, intelligent transportation, automated access control.

1. Introduction

Rapid urbanization and the surge in vehicle ownership have intensified parking challenges in cities, resulting in congestion, inefficient use of space, and heightened environmental degradation. Traditional parking systems relying on manual monitoring or outdated sensors fail to deliver accurate, real-time occupancy information. This lack of precision not only frustrates drivers but also increases traffic congestion and fuel consumption.

The IoT introduces a transformative opportunity for modernizing parking management. IoT-enabled parking systems leverage sensors, connectivity, and smart analytics to autonomously monitor space availability and guide drivers efficiently, reducing search times and emissions. SPS using IoT technology comprise various components, including on-site sensor networks, cloud platforms, and user interfaces forming an integrated ecosystem that empowers both drivers and operators with actionable insights in real time.

Research on smart parking systems has evolved towards IoT-enabled architectures and computer vision-based detection methods, both aiming to improve accuracy, scalability, and user experience.

IoT and Systems Architectures:

Several works have explored end-to-end IoT smart parking systems integrating LoRa sensors, edge computing, and dynamic pricing to reduce congestion [1]. Other studies have

implemented scalable solutions using LoRaWAN and Kubernetes for real-time telemetry and monitoring [2]. Comprehensive reviews have analyzed system types, sensing technologies, and communication protocols [3]. Parking prediction surveys have examined datasets, methods, and evaluation practices, highlighting the need for standardized benchmarks [4], while others emphasize integrating multiple data sources such as cameras, meters, and mobile applications for improved prediction accuracy [5].

Vision and Deep Learning Approaches:

Recent research documents the shift from traditional image processing to deep learning models such as CNNs and transformers for parking slot detection and occupancy classification [6], [7]. Lightweight implementations, such as Improved MobileNetV3, enable real-time detection on embedded platforms [8]. Integrated solutions combining automatic number plate recognition (ANPR), booking, and allocation have been developed, with real-world testing demonstrating reduced latency and improved user satisfaction [9]. A broader review of detection techniques, challenges, and opportunities provides insights into emerging trends [10].

While vision-based systems offer high accuracy, they require significant computation, high-bandwidth transmission, and are sensitive to lighting/weather conditions. The proposed system in this work addresses these issues by using infrared (IR) sensors, an ESP32 microcontroller, LCD display, keypad, and servo motor to detect and manage parking slots. Unlike high-cost vision-based setups, the IR-sensor approach ensures low power consumption, easy deployment, and consistent performance in both day and night conditions. Additionally, integrating IoT connectivity enables real-time updates, reserved access for staff/VIP zones, and automated entry control features not fully addressed in several existing studies. This makes the system both cost-effective and practical for mid-sized urban facilities.

3. Methodology:

The proposed IoT-enabled car parking system employs the NodeMCU ESP32 microcontroller as the central control unit, leveraging its integrated Wi-Fi for seamless communication with a Telegram Bot via the Callmebot API. Upon initialization, the ESP32 configures all hardware components including IR sensors, a 20×4 LCD, a servo motor, an LED indicator, and a 4×1 keypad, while displaying a welcome message to indicate system readiness.

Each parking slot is equipped with an IR sensor that continuously detects vehicle presence, sending HIGH or LOW signals to indicate occupancy status. These inputs are processed in real time to update the LCD display, showing “Occupied” or “Vacant” for each slot. When a vehicle is detected, the system records the start time, calculates the elapsed duration using the `millis()` function, and determines parking charges according to a predefined tariff formula.

The system enhances user convenience through real-time remote notifications, sending slot number, elapsed time, and computed charges via Telegram. Secure access control is implemented using a PIN-based mechanism through the 4×1 keypad; correct PIN entry triggers the servo motor to open a barrier for a predefined duration before automatically closing. The ESP32 executes its core functionality through two main routines: `setup()`, responsible for initialization and network

configuration, and loop(), which continuously manages sensor monitoring, LCD updates, keypad authentication, servo actuation, and notification dispatch.

The block diagram (Fig.1) illustrates the system architecture, where the ESP32 serves as the processing hub managing all connected modules. The keypad provides user input for access authentication, while the servo motor acts as a physical actuator for gate control. The LED serves as a visual status indicator, and the LCD module displays slot availability and system messages. IR sensors act as the primary detection units for vehicle presence in each slot. The ESP32’s Wi-Fi capability facilitates integration with the Telegram Bot for IoT-based monitoring and control, enabling remote status updates and notifications to users. This integrated design ensures accurate occupancy tracking, controlled entry, and instant user communication, making it a reliable and efficient smart parking solution.

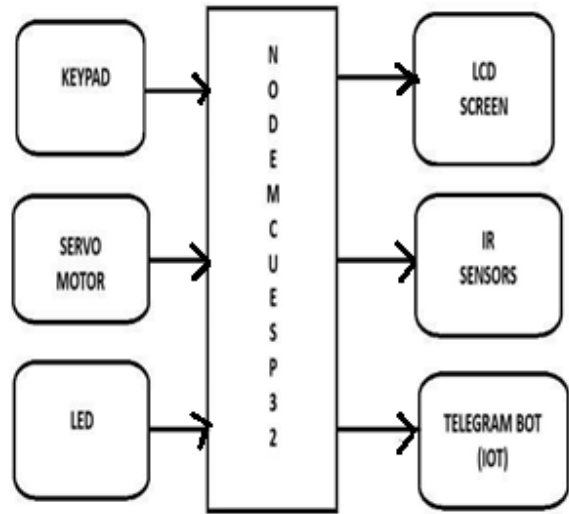


Fig1: Block diagram representation

4. Results and Analysis

The developed ESP32-based parking management system was tested for functionality, accuracy, and responsiveness. The prototype consists of IR sensors for slot occupancy detection, an LCD display for on-site status updates, a keypad–servo system for reserved zone access, and a Telegram bot for remote notifications.

System Output Overview

Fig.2 shows the assembled ESP32-based prototype, including sensors, display, and actuators.



Fig.2: System Model

When all slots are occupied, the LCD updates to “Occupied” for each slot. Fully Occupied Layout and LCD display is shown in Figs. 3.1 & 3.2. The fig 4.1 is the layout of randomly filled slots with few slots being occupied and few being empty. The corresponding LCD display is as shown in fig 4.2. The fig 5.1 is the layout of the reserved zone layout which represents the parking area meant for working staffs and VIP. The fig 5.2 shows the security system ie, the keyboard and servomotor interfacing for the restricted entry on for staffs.

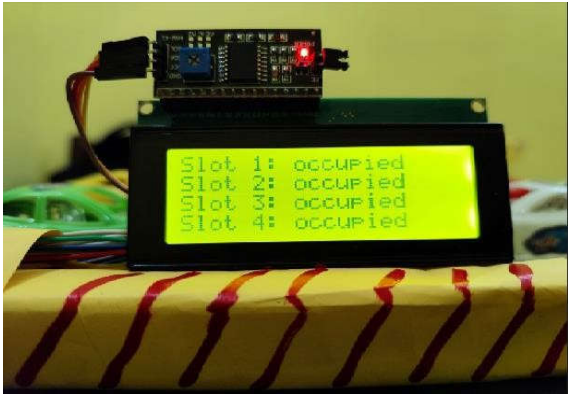


Fig.3.1 & 3.2: Fully occupied slot layout and LCD display

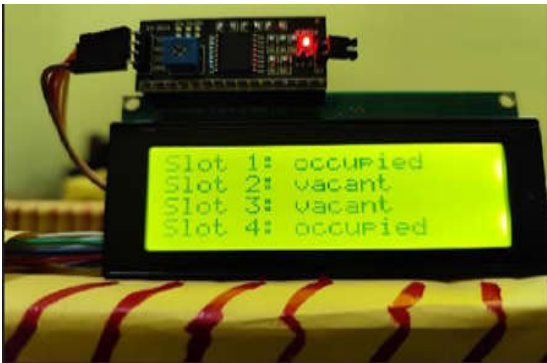


Fig 4.1 & 4.2: Occupancy layout and display



Fig 5.1 & 5.2: Layout of reserved zone and its security

The fig 6 is the image of notifications received via Telegram bot for each slots and is continuously updated along with the parking fee and slot number information.



Fig 6: Notification via Telegram bot

Performance Analysis

- **Detection Accuracy:** IR sensors consistently detected vehicle presence/absence in all tested scenarios. Accuracy was near 100% in controlled indoor lighting. Minor false triggers occurred in strong sunlight, suggesting the need for shielding or alternative sensors in outdoor deployment.
- **Real-Time Updates:** Telegram notifications were delivered within 1–3 seconds of an event. This delay is negligible for practical use and ensures near-instantaneous remote monitoring.

- **User Interface:** The LCD display was clear, easy to read, and updated instantly upon occupancy changes. The separation of public and reserved slot status was intuitive.
- **Reserved Zone Security:** The PIN-based access control worked reliably, ensuring only authorized users could enter. The combination of keypad, servo barrier, and LED alert provided both convenience and security.
- **Charge Computation:** Parking fee calculations were accurate and consistent with the configured rate, using precise elapsed time tracking.
- **System Stability:** The ESP32 maintained uninterrupted Wi-Fi connectivity during 3 hours of continuous testing, with no missed detections or message failures.

Comparison with Traditional Methods

Feature	Traditional Parking System	Proposed ESP32-based System
Slot Monitoring	Manual checking by guards	Automated via IR sensors
Status Display	Paper records or verbal	Real-time LCD display
Access Control	Manual verification	Automated keypad-servo gate
Notification System	Not available	Instant Telegram alerts
Charge Calculation	Manual/time ticket-based	Automated & precise
Response Time	Minutes to hours	1–3 seconds
Manpower Requirement	High	Low
Error Probability	High (human error)	Low (sensor-based)

The proposed system significantly improves efficiency, reduces human error, and enhances user convenience compared to traditional parking management. It offers a cost-effective, low-maintenance alternative to manpower-dependent parking systems and demonstrates strong potential for deployment in small-to-medium-sized parking facilities.

Conclusion:

IoT integration in smart parking systems allows for real-time parking space monitoring, which improves efficiency, compliance, and user convenience while lowering emissions, traffic, and search times. These systems play a vital role in sustainable urban growth and smarter mobility. In order to further optimize resource consumption and improve user experience, future improvements might incorporate dynamic pricing models, AI integration for predictive analytics, and interoperability with smart transportation networks.

References:

- [1] L. Santos *et al.*, “Smart parking system with dynamic pricing, edge-cloud computing and LoRa,” *Sensors*, vol. 20, no. 24, art. 7416, Dec. 2020, doi: 10.3390/s20247416.
- [2] R. Centelles *et al.*, “A smart parking solution architecture based on LoRaWAN and Kubernetes,” *Applied Sciences*, vol. 10, no. 18, 6141, Sept. 2020, doi: 10.3390/app10186141.
- [3] M. A. Fahim, M. Hasan, and M. A. Chowdhury, “Smart parking systems: comprehensive review based on various aspects,” *Heliyon*, vol. 7, no. 5, e07050, May 2021, doi: 10.1016/j.heliyon.2021.e07050.
- [4] X. Lin, E. Rivano, and J.-M. Le Mouél, “A survey of parking prediction: Datasets, methods, and challenges,” *IEEE Trans. Intell. Transp. Syst.*, 2023, doi: 10.1109/TITS.2023.3310697.
- [5] H. Ding, B. Cheng, X. Lv, and W. Zhao, “A review of research on urban parking prediction,” *J. Traffic Transp. Eng. (English Edition)*, 2024, doi: 10.1016/j.jtte.2024.06.008.
- [6] G. S. Wong, K. O. M. Goh, C. Tee, and A. Q. Md Sabri, “Review of vision-based deep learning parking slot detection on surround view images,” *Sensors*, vol. 23, no. 15, art. 6869, Aug. 2023, doi: 10.3390/s23156869.
- [7] C. Howard *et al.*, “A systematic review on computer vision-based parking lot management applied on public datasets,” *Expert Syst. Appl.*, vol. 198, 116731, 2022, doi: 10.1016/j.eswa.2022.116731.
- [8] Y. Yuldashev, M. Mukhiddinov, A. B. Abdusalomov, R. Nasimov, and J. Cho, “Parking lot occupancy detection with improved MobileNetV3,” *Sensors*, vol. 23, no. 17, art. 7642, Sept. 2023; correction in *Sensors*, vol. 24, no. 16, 5236, 2024, doi: 10.3390/s23177642.
- [9] A. O. Elfaki, W. Messoudi, A. Bushnag, S. Abuzneid, and T. Alhmiedat, “A smart real-time parking control and monitoring system,” *Sensors*, vol. 23, no. 24, art. 9741, Dec. 2023, doi: 10.3390/s23249741.
- [10] Q. Xia *et al.*, “Multi-Dimensional research and progress in parking space detection: A review,” *Electronics*, vol. 14, no. 4, 748, 2025, doi: 10.3390/electronics14040748.