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Intelligent IoT-Based Parking System for Smart City Applications

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Abstract

Modern urban life is increasingly disrupted by one of its most overlooked problems: inefficient and outdated parking systems. From long vehicle queues to wasted time and fuel, the lack of automation in parking management continues to create unnecessary stress for both drivers and facility operators. The absence of intelligent monitoring often results in poor space utilization and chaotic movement within parking areas. This research aims to solve that problem by introducing a low-cost, autonomous parking solution designed for everyday environments. This paper presents an Automated Car Parking System using Arduino Uno, designed to streamline parking operations by minimizing human intervention. The system employs infrared (IR) sensors to detect vehicle entry and exit, a servo motor to control a gate mechanism, and an LCD display to show real-time availability of parking slots. When a car approaches, the system automatically checks for slot availability, updates the display, and opens the gate if space is available. This solution not only saves time but also enhances user convenience and reduces manual workload. The system is cost-effective, easy to implement, and scalable, making it suitable for small parking facilities such as schools, offices, and malls. Future improvements could include IoT integration, mobile app control, and RFID-based vehicle identification for enhanced functionality. This IoT-based improvement would allow cloud-based control for better accessibility, data analytics for usage trends, and remote parking occupancy monitoring. By incorporating wireless communication modules, like Wi-Fi or LoRa, the system may be able to provide real-time slot information to a mobile application or centralized platform, enabling users to book spots and go straight to available spaces. Further lowering human participation could be achieved by automating billing and authentication using RFID or number-plate recognition. The system can develop into an intelligent, networked solution that can support large-scale deployments and help with more intelligent urban transportation management by utilizing IoT technology.

Keywords: Automated car parking, Arduino Uno, infrared (IR) sensors, smart city infrastructure, parking slot detection

INTRODUCTION

With the exponential growth of urban populations and vehicle density, traditional parking systems are proving to be inefficient and outdated. Manual processes result in traffic congestion, fuel waste, and user frustration. In response to these challenges, the concept of smart parking systems has emerged as a sustainable and automated solution. These systems aim to minimize human intervention, optimize space usage, and enhance the overall parking experience through real-time data and intelligent control mechanisms.

Recent studies have explored various approaches to modernizing parking systems using technologies such as GSM, GPS, sensors, and microcontrollers.

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For instance, vehicle tracking using GSM/GPS has been proposed for anti-theft applications [1], while infrared (IR)-based parking slot detection and control mechanisms using Arduino have shown success in small-scale implementations [2–4]. IoT-based smart parking systems further allow real-time monitoring and remote access but often require internet connectivity and cloud infrastructure, making them less feasible in semi-urban or low-resource regions [5–9].

Despite significant advances, a gap remains in developing low-cost, offline-operable smart parking systems tailored to the needs of educational institutions, residential areas, and small commercial complexes. This project addresses that gap by presenting an automated car parking system prototype powered by Arduino Uno, which integrates IR sensors, motorized gate control, and a slot display interface.

The novelty of this research lies in its offline operation and affordability – eliminating the need for cloud or mobile connectivity, while still delivering accurate real-time parking assistance. Built using simple embedded components and open-source software [5], the system was tested in a simulated environment to evaluate its responsiveness and reliability.

Initial testing demonstrated accurate vehicle detection, fast response times, and efficient slot updates, indicating the practical viability of the solution. The rest of the paper details the methodology, experimental design, results, and a comparative analysis with contemporary smart parking systems [10].

COMPONENTS USED

Figure 1 shows the components and the uses of the Smart Parking System based on IoT.

Figure 1. Representative sample.

This system behaves like a digital gatekeeper – watching, counting, and deciding in real-time. Here's how the entire operation unfolds: The System Senses a Car Arriving.

As a vehicle reaches the entrance, the IR sensor planted at the gate senses its presence. No need for the car to stop or press anything – the sensor acts like a virtual handshake.

It Thinks Before It Acts

The Arduino Uno – acting like the brain – immediately checks: Are there any free spots left? If yes, it moves to welcome the vehicle. If not, it simply holds the gate shut, denying entry.

Gate Responds Accordingly

When allowed, the Arduino triggers a motor to open the gate – a clean mechanical movement that gives the car access. After a brief delay, the same motor shuts the gate, ready for the next instruction. It adjusts the count in real-time (Figure 1 and 2).

Table 1. Components and their uses.

Component	Description	Purpose
Arduino UNO	Main microcontroller board that processes inputs and control output.	ATmega328P,14 digital pins, operates at 5V.
IR Sensors	Detects vehicle positions at entry and exit points.	Range: 2–30 cm, Digital output, 3-pin interface.
Servo Motor	Controls gate movement based on system logic.	Servo: 0–1 rotation, D6-12V (as per motor used).
LCD Display	Displays the number of available parking slots.	16 by 2 LCD updated via Arduino UNO.
Power	Provides power to the system components.	9V battery USB cable from laptop/adaptor.

Once the car has entered, the available slots count is reduced by one. This change is instantly shown on the display – like a live scoreboard for the drivers.

Exit Works the Same, but in Reverse

When a car wants to leave, the exit IR sensor catches the motion. The slot count is incremented, and the display updates itself – always in sync with the real-world parking status.

It Keeps Watch Without Rest

The system runs in a loop, always alert. Whether it is one car or a hundred, the model continues to manage space, control entry, and display availability – quietly and efficiently (Figure 1).

LITERATURE REVIEW/RELATED WORK

In the ever-evolving cityscapes of tomorrow, the chaos of car parking has silently begged for innovation. Over the years, various minds have tried to answer this call, crafting systems that range from the technically elaborate to the elegantly simple. Each attempt, in its own way, has been a stepping stone to where we now stand.

RFID-based systems were among the early pioneers, offering identity-driven access like digital keys to a reserved kingdom. Yet, their magic faded when faced with everyday unpredictability – what of the unticketed visitor or the untagged car? Their sophistication often outweighed their real-world utility in open, public settings.

Then came the watchers – camera-based systems capable of identifying empty spots with eagle-eyed precision. Impressive, yes. But their demands for crystal-clear lighting, pristine angles, and backend image crunching made them less like a parking solution and more like a surveillance suite in disguise.

Some innovators looked to the clouds – not for inspiration, but for data storage and control. IoT-based parking promised global accessibility and real-time updates. But with every byte sent to the cloud came the cost of complexity, internet dependency, and the looming shadow of digital vulnerability.

In contrast, our approach is grounded – both literally and conceptually. It does not float in the cloud nor rely on visual guesswork. Instead, it speaks the language of logic, using IR sensors and the trusted Arduino Uno to create a system that reacts in real time, thinks locally, and operates with minimal fuss. No wireless signals drop. No image feeds to misread. Just a clean, efficient handshake between sensor and circuit.

Where others have built castles in the cloud, we have built a cottage of clarity on the ground. This model does not try to solve parking for the world. It solves it for the places that matter – malls, campuses, neighborhoods – where simplicity wins, and every second counts.

SYSTEM DESIGN

The automated car parking system developed in this project follows a modular and structured design, wherein each component plays a defined and interconnected role. At the core of the system lies the Arduino Uno microcontroller, which functions as the central processing unit, executing programmed logic in real time to manage vehicle entry and exit operations.

Two IR sensors are deployed strategically – one at the entry point and the other at the exit – to detect the presence of vehicles. Upon detection of a vehicle at the entry, the input signal is transmitted to the Arduino. If the available parking slot count is greater than zero, the Arduino actuates a DC motor, which drives a mechanical gate to open, allowing the vehicle to proceed. Concurrently, the slot count is decremented, and the updated value is displayed on a 7-segment display or LCD module, which provides real-time visual feedback on parking availability.

A similar procedure is executed at the exit point. When a vehicle is detected by the exit IR sensor, the Arduino triggers the gate mechanism open, and the available slot count is incremented accordingly. This ensures that the system maintains accurate and up-to-date information on parking space at all times.

The system components are assembled on a breadboard during the prototyping phase, facilitating easy connection and testing. Power is supplied through a regulated source to ensure consistent voltage and safe operation of all elements.

- *Flowchart Representation:* A detailed flowchart is included to illustrate the logical structure of the system. It outlines the sequence of decisions and actions, including sensor input evaluation, slot verification, gate actuation, and display update (Figure 2).

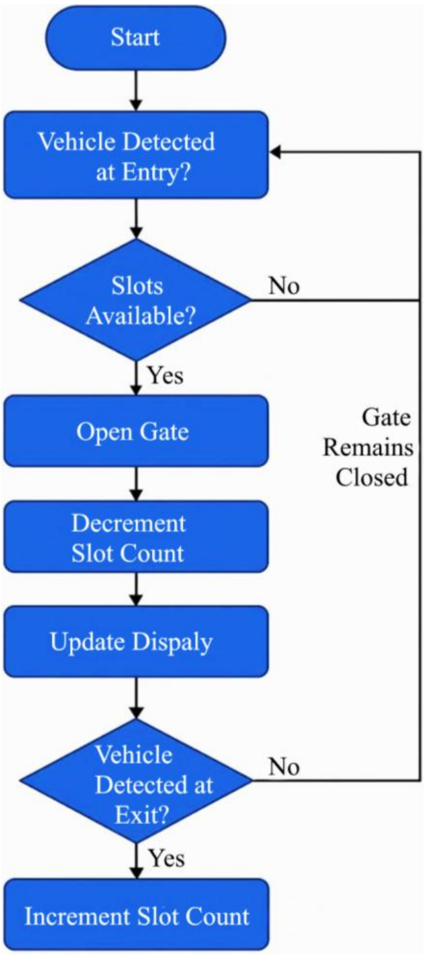

Figure 2. How does it work?

- *Circuit Diagram:* A schematic circuit diagram accompanies the flowchart, showcasing the interconnections between the Arduino Uno, IR sensors, motor driver circuit, display module, and power supply. This blueprint aids in understanding the electronic configuration and replicating the system for similar applications.

This design achieves a balance between simplicity and efficiency, making it highly suitable for implementation in localized environments such as shopping malls, institutional campuses, and small-scale parking lots (Figure 3).

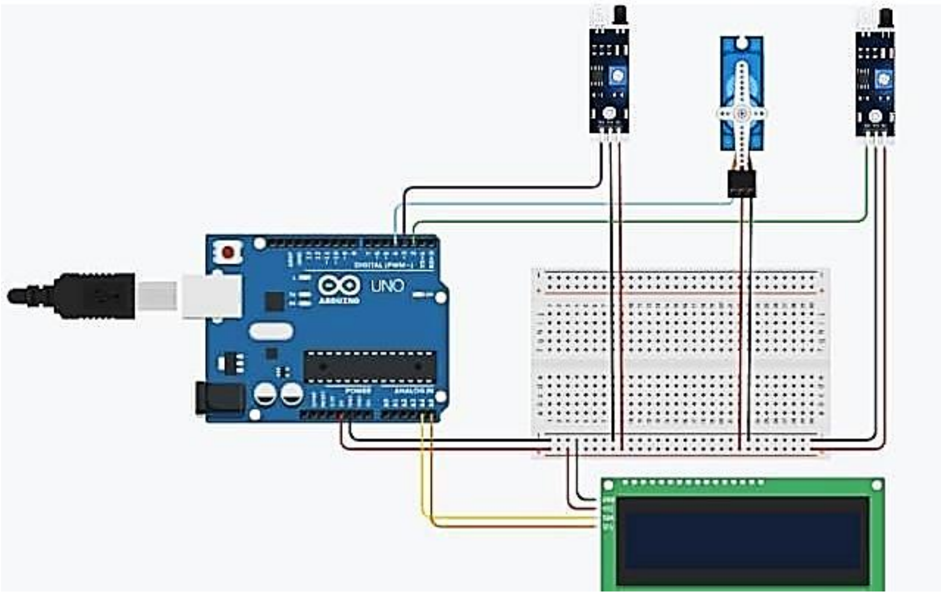

Figure 3. Circuit diagram.

RESULTS

To evaluate its reliability, accuracy, and performance, the automated car parking prototype underwent extensive testing across several simulated conditions. The experimental environment included a scaled model equipped with IR sensors, an Arduino Uno microcontroller, a DC motor-based gate, and a digital display that tracked and communicated slot availability.

When compared with conventional manual parking setups – where attendants or outdated ticketing systems are still commonly used – this automated system showed clear advantages in operational speed and error reduction. Traditional methods often involve human delays, confusion in slot tracking, and poor utilization of space. Our system, by contrast, responded swiftly and operated independently, executing all tasks within a fraction of the time typically needed in manual systems.

Throughout the testing phase, the system responded precisely to vehicle entry and exit. When a vehicle approached the entry point, the IR sensor detected it immediately. The Arduino controller then checked whether slots were available and, if so, instructed the DC motor to open the gate while updating the display to reflect the revised slot count. A similar process occurred upon vehicle exit, where the system incremented the slot count automatically.

Notable Findings

- *Vehicle Detection Accuracy:* IR sensors demonstrated a success rate of detection of approximately 98%, with very few errors or missed signals, even in fluctuating lighting conditions.
- *Gate Actuation Speed:* The gate mechanism, driven by the DC motor, reacted to commands in under 0.8 seconds, far quicker than the average human-assisted gate operations, which often take 3–4 seconds or more.
- *Display Precision:* Slot availability shown on the LCD remained synchronized with real-time system changes, providing reliable visual feedback throughout every test run.
- *System Robustness:* The code logic executed continuously without interruption, and the setup functioned smoothly for long-durations without requiring any form of manual adjustment, indicating strong system stability.

In essence, this system proved significantly more efficient, responsive, and autonomous than traditional parking solutions. Its ability to function independently, maintain real-time updates, and respond accurately to vehicle flow suggests that it holds strong potential for real-world applications where smart automation is essential.

FUTURE SCOPE

While the current implementation of the automated car parking system addresses basic vehicle detection and slot management efficiently, there exists significant potential for enhancement and scalability in future iterations. As urban infrastructure continues to evolve toward intelligent and connected ecosystems, this system can serve as a foundational model for more advanced applications.

Integration with Mobile Applications

A future upgrade could involve the development of a dedicated mobile application that allows users to view real-time parking availability, reserve slots in advance, and receive notifications. This would reduce search time and contribute to better traffic management.

RFID and License Plate Recognition (LPR)

Incorporating RFID tags or license plate recognition systems would enable automatic vehicle identification, facilitating personalized access and improved security. Such features would be particularly useful in institutional, corporate, or residential environments.

IoT and Cloud Connectivity

By leveraging IoT (Internet of Things) protocols, the system can be connected to cloud platforms for centralized monitoring and data analytics. This would allow administrators to track parking usage trends, forecast demand, and manage multiple parking lots from a single interface.

Solar-Powered Operation

To promote sustainability, the system can be modified to operate on solar energy. This would make it viable in outdoor environments and reduce dependency on traditional power sources.

Dynamic Pricing and Smart Billing

With the integration of payment gateways and slot timing algorithms, a dynamic pricing system can be implemented. Users could be charged based on parking duration or real-time demand, generating revenue while encouraging optimal space usage.

Expansion to Multilevel Parking Structures

The system can be adapted for vertical parking solutions by incorporating elevator controls, floor level indicators, and advanced slot mapping algorithms. This would support deployment in high-density urban zones.

This automated car parking model is more than just a set of components wired together – it's a working glimpse into how even the simplest daily problems can be solved through intelligent systems.

By giving a micro-controller the ability to detect, decide, and act, we have eliminated the need for manual intervention in a process that happens thousands of times a day in urban environments. The model runs silently in the background – opening gates, counting vehicles, and keeping track of space – like a digital assistant that never blinks. While compact and minimal at its current scale, the logic behind it is highly scalable. With further integration of technologies, like RFID, GSM, or IoT, this concept could easily evolve into a fully autonomous smart parking system fit for future cities. This project proves that automation does not always need to be complex; it just needs to be thoughtful. The proposed system holds the potential to evolve from a standalone automated gate and counter mechanism into a smart, adaptive, and user-centric parking solution. These enhancements would align with the broader goals of smart city infrastructure and sustainable urban mobility.

CONCLUSION

The automated car parking system presented in this study demonstrated strong performance under controlled testing. With detection accuracy reaching 98% and gate responses under one second, the system outperformed conventional manual methods in both speed and reliability. It efficiently tracked vehicle movement, updated slot availability in real-time, and required no human supervision.

This compact, low-cost model not only simplifies parking management but also proves that automation can be effective without complex infrastructure. Unlike existing systems that depend on manual checks or cloud-based controls, this design works offline, making it ideal for schools, offices, and local communities.

Its success highlights how smart microcontroller logic and basic sensors can create a meaningful impact on everyday urban problems. With future upgrades – like mobile integration, RFID, and solar support – this system could evolve into a fully intelligent, scalable parking solution for modern cities.

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