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A SMARTER WAY TO PARK: THE FUTURE OF CAR PARKING

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ABSTRACT
Increased demand for parking solutions has led to the development of intelligent parking systems. This article describes a system that simplifies the parking process using infrared sensors and microcontroller-based architectures. The system automates basic tasks such as inputting vehicle movements and monitoring parking spaces. Embedded microcontroller sensor input and control components programmed in the C process, such as servo motors for gate automation and LCD displays that provide immediate availability updates. Critical hardware components such as Arduino-Nano, power supplies, LED displays, infrared LED transmitters, and servo motors are integrated into the design to ensure cost-effectiveness and scalability. This system can adapt to several parking spaces and solve urban parking problems. The concept of intelligent parking effectively improves modern park management by efficiently using space, reducing traffic congestion and increasing user comfort.
Keyword: Smart Car Parking System, IR Sensors, Microcontroller, Automated Parking, Real-Time Updates

I. INTRODUCTION
With the rapid increase in the number of vehicles in urban areas, parking management has become a significant challenge. Traditional manual parking methods are often inefficient, slow, and inconvenient for users, highlighting the need for advanced solutions. Automated parking technology has emerged as a promising alternative, offering better space utilization, reduced human effort, and improved reliability [1][2].
Modern automated parking systems utilize infrared sensors, microcontrollers, and servo motors to enhance efficiency and user convenience. These systems enable real-time monitoring of parking spaces, control vehicle movement, and display parking availability on an LCD screen, making the process more streamlined [3][4]. Additionally, automated gate control through servo motors reduces delays and congestion at parking lots, eliminating the need for drivers to search for spaces manually [5]. Research has shown that a simple setup involving two infrared sensors can be highly effective in managing parking and monitoring occupancy levels [6].
The integration of IoT-based parking solutions has demonstrated significant improvements in workplace parking efficiency. These systems facilitate remote monitoring, automated space allocation, and data-driven decision-making to optimize parking operations [7][8][9]. Emerging studies further emphasize the role of cloud computing, machine learning, and blockchain in enhancing smart parking infrastructure. Cloud technology provides scalable data storage and real-time access, while machine learning algorithms help predict space availability. Meanwhile, blockchain ensures secure and transparent transactions for automated parking payments [10][11][12].
Looking ahead, advancements such as deep learning-based parking detection and the implementation of 5G-enabled IoT networks are expected to transform urban parking management. These innovations will enhance communication between vehicles and infrastructure, leading to faster response times and improved traffic flow [13][14][15]. The adoption of these technologies aims to develop smarter urban economies, reduce congestion, and meet the rising demand for parking in densely populated cities.

II. BLOCK DIAGRAM

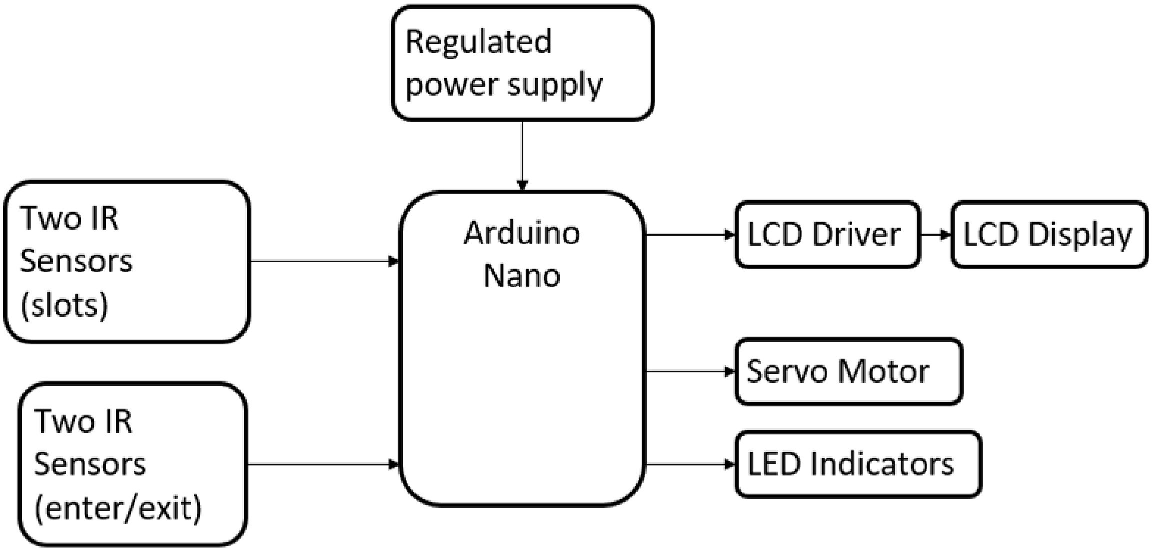

Fig.1: Block Diagram of smart parking system

In Fig 1. The block diagram provides a visual representation of its core components and their interactions. In the centre of the system is Arduino -nano (Atmega328p), which acts as a central processing unit, which processes the inputs of the sensor and controls various outputs. Two infrared (IR) sensors are located at the input and output points in the parking lot. These sensors recognize the presence of vehicles with reflective infrared rays and send actual data to the Arduino. Based on this input, Arduino determines the park's status from the parking lot and its corresponding action. To adjust access to the vehicle, the servo engine operates a barrier or gate and moves within 0° to 180, a LCD Display (16x2 Alphanumeric) provides real-time park status updates for user comfort. Receives entries from the LCD driver that is controlled by the Arduino and displays available and occupied slots. Led light-shaped visual indicators further improve usability, a Regulated Power Supply for Arduino and Sensors Stable operation of all components with 5V DC supply and 12V DC power supply of the servo engine if necessary. We guarantee that, the entire system is designed for scalability, allowing additional sensors and slots to integrate larger parking spaces. Using embedded C programming via Arduino ide, the system enables real-time monitoring, efficient parking management and a seamless user experience which surpasses the traditional approach.

Hardware Components

The smart parking system consists of the following hardware components:

Power Supply: Provides 5V DC for the Arduino Nano and sensors, while the servo motor operates on 12V DC if required. A regulated power supply ensures stable and uninterrupted operation.

Microcontroller: The system uses an Arduino Nano (ATmega328P) operating at 5V DC, with 14 digital I/O pins and 8 analogue input pins for seamless integration with sensors and actuators.

IR Sensors: Used for vehicle detection, these sensors operate at 5V DC with a detection range of 2-10 cm. They function based on reflective infrared light technology.

Servo Motor: Operates within a voltage range of 4.8V to 6V DC, with a torque capacity of 2.5-5 kg/cm and an angular range of 0° to 180°. It is responsible for controlling the automated gate mechanism.

LCD Display: A 16x2 alphanumeric display operating at 5V DC. It provides real-time updates on parking space availability and uses a parallel connection with a contrast adjustment potentiometer for better visibility.

LED Indicators: Operate at 2-3V with a current-limiting resistor. Green LEDs indicate vacant spaces, while red LEDs signify occupied spots.

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Overall System: Designed for scalability, allowing the integration of additional sensors and parking slots. Components are connected through wired communication for reliability and minimal latency. The system is programmed using Embedded C via the Arduino IDE, ensuring efficient and low-power operation.

III. METHODOLOGY

The proposed automated parking system integrates a variety of electronic components to ensure efficient parking management. This system is equipped with 5 VV power supplies regulated by Arduino-Nano and sensors, but individual 12 VV power supplies are used for the servo motor if necessary. The Arduino Nano (Atmega328p) acts as a central microcontroller and processes data from Infrared (IR) sensors (IR) and controllable system processes. IR sensors with a detection range of 2-10 cm are strategically located to recognize the presence of the vehicle using reflected red light. Based on the sensor input, it operates within a voltage range of 4.8 V to 6 V DC, within a torque of 2.5 to 5 kg/cm, and by 0° to angle range of 0° to angle range, manages automatic gate movement. 180°°°C set. Park status is displayed on a 16x2 alphanumeric LCD screen that operates on 5 V-DC and includes real-time updates for slot availability. The LED indicator helps for quick visual identification, where the green LED means a fleece slit, while the red LED indicates occupancy. The entire system runs with embedded C programming via Arduino-ide with wired communication to ensure seamless interaction between the components. The system developed for scalability can be expanded by absorbing additional sensors and slots into larger parking spaces. By using intelligent IoT-based parking technology and automated control mechanisms, this approach significantly improves efficiency, minimizes human intervention, and improves the general user experience.

A more intelligent parking method is an intelligent park management solution that uses sensors, microcontrollers and automated components to optimize vehicle parking. Using infrared (IR) sensors for vehicle recognition, the system ensures efficient use of space and actual monitoring by using an Arduino Nano for processing and a servo motor for barrier control. The LCD display provides live park status updates, while the LED indicators provide fast visual information for available and occupied slots. The system is seamlessly developed and integrated for scalability to additional sensors and parking spaces, making it a reliable and efficient intelligent park solution.

IV. EXPERIMENTAL SETUP

The intelligent parking system consists of a microcontroller-based framework with various sensors and actuators for automating parking management. The Arduino Nano acts as the central processing unit, receiving input from the infrared (IR) sensor at the entrance and exit points to detect vehicle movement. The servo motor controls the automated gate, allowing vehicles to enter and exit based on real-time occupancy data.

A 16x2 LCD display provides users with updates on parking status. The entire system operates with a regulated 5V DC power supply to ensure stable and efficient functionality. A wired connection links the components for reliable communication and minimal latency.

To verify the effectiveness of the system, the prototype was tested in a controlled environment with simulated vehicle movement. The IR sensor successfully detected the presence of vehicles with high accuracy and triggered the servo motor to operate the gate. The LCD and LED indicators consistently updated in real time, providing clear guidance on parking space availability. This setup proved to be energy-efficient, low-maintenance, and easily scalable, making it a practical solution for modern parking management systems.

Parameters and Specifications of the Smart Parking System :

Operating Voltage: 5V DC (Arduino Nano, sensors), 12V DC (servo motor)
Microcontroller: Arduino Nano (ATmega328P)
IR Sensor Detection Range: 2-10 cm
Servo Motor Voltage: 4.8V - 6V DC

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Servo Motor Torque: 2.5-5 kg/cm
Servo Motor Angular Range: 0° - 180°
LCD Display Type: 16x2 alphanumeric
LCD Operating Voltage: 5V DC
LED Indicator Voltage: 2-3V (with current-limiting resistor)
LED Colour Indications: Green (vacant), Red (occupied)
Communication Type: Wired connections between components
Programming Language: Embedded C (via Arduino IDE)
Power Supply Stability: Regulated for uninterrupted operation
Scalability: Expandable with additional sensors and slots

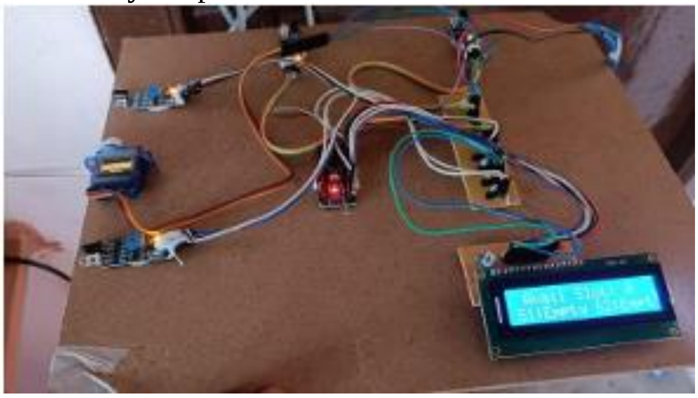

Fig.2: Smart parking system kit front and top view

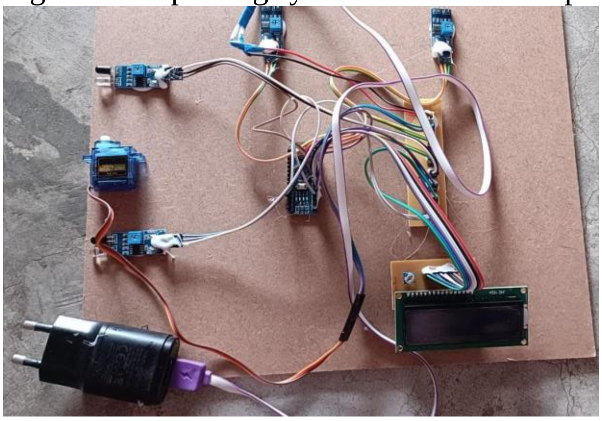

Fig.3: Smart parking system kit top view

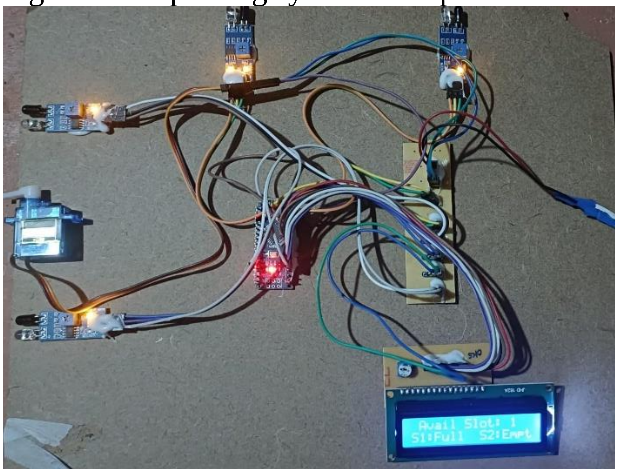

Fig.4: Smart parking system kit in working condition

Figures 2, 3, and 4 shows a detailed visual representation of the intelligent parking system prototype. Figure 2 shows both the front and top views of the assembled kit, highlighting key components such as the Arduino Nano, IR sensor, servo motor, LCD display, and LED indicators. Figure 3 shows a clear top view, illustrating the placement of sensors and electronic modules for efficient vehicle detection and gate operation. Figure 4 illustrates the system's operation, showing real-time parking detection, automatic movement of the barrier, and status updates on the LCD screen. These pictures demonstrate the functional design and working principle of the intelligent parking prototype.

V. Results and Discussion

The implementation of intelligent parking systems significantly improves parking efficiency, reduces traffic congestion, and optimizes space use. In actual testing, the tests significantly reduced the time required for drivers to search for available locations and minimize park delays. Integration of infrared (IR) sensors also provided accurate vehicle detection under different lighting conditions to ensure reliable occupancy monitoring. Automated servo motor control barrier improved input and output flow, eliminating manual intervention and reducing latency. Additionally, the LCD display and LED indicator effectively guide the driver to available locations, improving user convenience. Compared to traditional parking methods, our system has proven efficient, cost-effective, and minimal maintenance thanks to its cable communication structure and low power consumption. The scalability of the system makes it easy to scale with additional sensors and slots, making it a customizable solution suitable for modern urban park management.

The performance of the prototype was evaluated under different test conditions, and key metrics were recorded to assess its efficiency. The table below summarizes the observed results:

Table 1: Prototype Performance Metrics

Test Condition	Detection Accuracy (%)	Response Time (ms)	Power Consumption (W)	Error Rate (%)
Normal Lighting	98.5	120	3.1	1.5
Low Lighting	96.8	135	3.3	3.2
High Traffic Flow	97.2	140	3.5	2.8
Harsh Environmental Simulations	95.6	155	3.7	4.4

VI. Conclusion

Automated parking systems successfully deal with the inefficiencies of traditional park management by integrating connected devices with microcontroller-based technology. Components such as infrared sensors, Arduino Nano, and servo motors ensure accurate vehicle recognition, efficient location tracking, and automatic gate operation. Real-time LCD display and LED indicators improve user convenience by reducing search time for parking spaces. This reduces fuel consumption and improves traffic flow. This project demonstrates the feasibility of an inexpensive, scalable, and efficient automated solution for parking spaces with potential uses in residential areas, commercial zones, and public parking facilities. Future progress, including improving Internet of Things (IoT) and user connectivity, can further enhance the functionality of the system and make it a critical component for the development of smart cities. Additionally, low power consumption and minimal maintenance requirements make it a sustainable, long-term solution. The adaptability of the framework allows for easy upgrades and ensures compatibility with new technologies. With urbanization increasing, such intelligent parking solutions will play a key role in reducing traffic congestion and improving overall traffic management.

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