Microcontroller-Based Automatic Parking System with Fire and Gas Monitoring

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***Abstract*—Efficient parking management has become a critical challenge due to rapid urbanization and increasing vehicle density. Manual parking systems often suffer from congestion, inefficient space utilization, and human error. This paper presents the design and implementation of a microcontroller-based Automatic Car Parking System capable of controlling vehicle entry and exit, monitoring parking slot availability, and enhancing safety through fire and gas detection. The system integrates IR sensors, a keypad, an LCD display, a servo motor, and LED indicators for parking control, while an MQ-2 gas sensor, buzzer, and relay provide real-time safety alerts. Experimental evaluation shows that the proposed system improves operational efficiency and safety, making it suitable for small-scale parking environments.**

***Index Terms*—Automatic Parking System, Microcontroller, IR Sensor, MQ-2 Gas Sensor, Embedded System, Safety Monitoring**

I. Introduction

Rapid urbanization and increasing vehicle ownership have intensified the need for efficient parking management, especially in densely populated urban areas. Traditional manual parking systems often cause traffic congestion, longer waiting times, inefficient use of parking spaces, and errors due to human intervention, negatively affecting user experience and overall traffic flow [1]. Automated parking systems have emerged as a solution by using sensors and embedded control technologies to manage vehicle entry, exit, and slot allocation more efficiently. Infrared (IR) and ultrasonic sensors are commonly used for detecting vehicle presence and monitoring slot availability due to their cost-effectiveness and reliability [1]. However, many existing systems focus primarily on automation and neglect safety considerations. Safety is crucial in parking environments, as enclosed areas are vulnerable to hazards like gas leaks and fire. MQ-2 gas sensors are widely used for detecting combustible gases and smoke in industrial and domestic applications [4], [7], but their integration into automated parking systems remains limited. This paper presents a microcontroller-based Automatic Car Parking System that automates parking operations while enhancing safety through integrated fire and gas detection. The system monitors parking slots, controls vehicle entry and exit, and provides real-time alerts using an MQ-2 sensor, buzzer, and relay module. By combining parking management and safety monitoring in a single platform, it improves efficiency, reduces human intervention, and increases overall safety in small-scale parking facilities [3], [8].

II. Literature Review

Previous research on automated parking systems has focused on improving vehicle detection, access control, and parking space utilization using embedded sensing technologies. IR and ultrasonic sensor-based systems are popular due to their low cost and reliable short-range detection [1], effectively identifying vehicles at entry points and parking slots, but they mainly provide basic automation and do not fully address safety concerns. RFID-based systems have been proposed to enhance access control and user identification by assigning unique tags to vehicles [2]. While these improve authentication and scalability, they increase hardware cost and complexity, limiting suitability for small-scale or low-budget environments. IoT-based parking systems offer real-time data collection, remote monitoring, and analytics via cloud platforms [3], improving flexibility and user convenience, but they rely heavily on network connectivity and backend infrastructure. Safety monitoring using gas and fire detection sensors, such as the MQ-2, has been widely studied in industrial and residential contexts [4], yet integration into automated parking systems remains limited. This work addresses this gap by combining parking automation with fire and gas detection on a single microcontroller-based platform, enhancing both efficiency and safety.

III. Methodology

A. Hardware Components

The Automatic Car Parking System uses a combination of sensors, actuators, and a microcontroller to enable automated vehicle management and safety monitoring. A microcontroller serves as the central unit for data processing and controlling all peripherals. An IR sensor detects vehicle presence at the entry gate, while a 4x4 keypad allows users to input their ID for access control. System status, slot availability, and warnings are displayed on an LCD. A servo motor operates the entrance gate, providing smooth opening and closing. Fire or gas detection is handled by the MQ-2 sensor [7], which triggers a buzzer for audible alerts and a relay module for activating safety mechanisms. Additionally, LED indicators provide visual feedback for entry status and emergencies.

B. Hardware Connections

Table I summarizes the hardware components along with their specific connections to the Arduino microcontroller.

TABLE I
Hardware Components and Connections

Component	Arduino Pin	Function
IR Sensor (Entry)	Digital 22	Detects vehicle presence at the entry gate [1]
Green LED	Digital 30	Indicates access allowed for vehicles
Red LED	Digital 31	Indicates access denied or fire alert
White LED	Digital 32	Entry indicator showing vehicle detection
MQ-2 Gas Sensor	Analog A0	Detects fire or gas leakage within parking area [4]
Buzzer	Digital 34	Provides audible alert during emergencies or wrong ID input
Relay Module	Digital 35	Activates safety systems during fire or gas detection
Servo Motor (Gate)	PWM 9	Opens and closes the entrance gate for vehicle access
4x4 Keypad Rows	Digital 36-39	Interfaces with keypad rows for user ID input
4x4 Keypad Columns	Digital 40-43	Interfaces with keypad columns for user ID input
LCD (I2C)	SDA/SCL (0x27)	Displays system status, slot availability, and alerts [6]

C. Software Components

The system software is developed using the Arduino IDE and programmed in embedded C to control all hardware components efficiently. Libraries such as `Servo.h` for gate control, `LiquidCrystal_I2C.h` for the LCD, and `Keypad.h` for user input simplify hardware interfacing and ensure reliable operation [5], [6]. During startup, the MQ-2 gas sensor calibrates to establish a baseline reading representing clean air [7], enabling accurate detection of smoke or combustible gases. The software continuously monitors sensor data, validates user IDs via the keypad, and controls actuators such as the servo motor, LEDs, buzzer, and relay. This integrated approach allows the system to manage vehicle entry and exit, update parking slot availability, and respond promptly to hazardous conditions, ensuring both efficient parking management and safety.

D. System Workflow

The system software, developed using Arduino IDE and embedded C, controls all hardware components efficiently. Libraries such as `Servo.h`, `LiquidCrystal_I2C.h`, and `Keypad.h` handle gate control, LCD display, and user input [5], [6].

At startup, the MQ-2 gas sensor calibrates to a baseline reading for accurate detection of smoke or combustible gases [7]. The software monitors sensors, validates user IDs, controls actuators, and updates slot availability, integrating parking management with real-time safety monitoring.

E. Application-Level Architecture

The application operates as a standalone embedded system where all decisions are processed locally by the microcontroller. This design ensures low latency, reliability, and independence from external communication infrastructure [8].

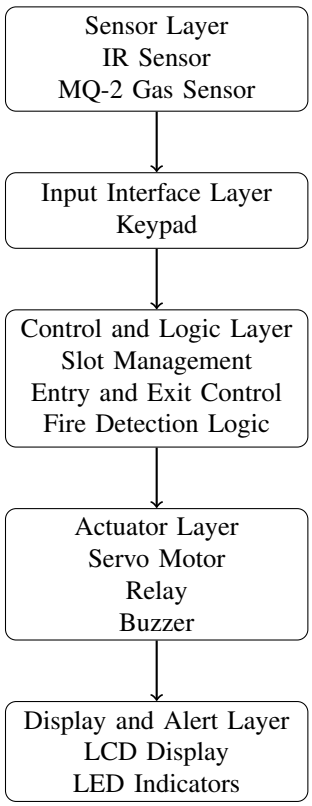

Fig. 1. Application-Level Architecture of the Automatic Car Parking System

IV. Results and Discussion

The developed prototype of the Automatic Car Parking System effectively managed vehicle entry and exit operations while maintaining accurate real-time tracking of parking slot availability. The system successfully validated user IDs through the keypad and assigned parking slots, providing immediate feedback via the LCD display and LED indicators, which users found clear and intuitive. The servo-controlled gate operated reliably, opening and closing smoothly in response to access authorization.

The integrated fire and gas detection module, using the MQ-2 sensor, responded promptly to elevated gas levels or smoke, triggering the buzzer, red LED, and relay to activate safety mechanisms without delay. This ensured that parking operations were temporarily halted during hazardous conditions, preventing potential accidents. Compared to conventional manual parking systems, the proposed system demonstrated significant improvements in operational efficiency, reduced human intervention, and enhanced overall safety [1], [4].

Furthermore, the system proved to be scalable for small to medium parking facilities, offering a cost-effective solution that combines automation and safety monitoring within a single embedded platform. User interaction was smooth and intuitive, confirming that the system can improve both user experience and traffic flow in parking environments.

V. Conclusion

This paper presented the design and implementation of a microcontroller-based Automatic Car Parking System with integrated fire and gas detection for enhanced safety. The proposed system efficiently automates vehicle entry and exit, monitors real-time slot availability, and responds promptly to hazardous conditions, ensuring both operational efficiency and user safety. Its compact design, cost-effectiveness, and reliable performance make it well-suited for small to medium-sized parking facilities.

Future enhancements may include wireless connectivity, mobile application integration for remote monitoring and control, and scalability for larger parking environments, further improving system accessibility, convenience, and overall functionality [3].

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