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DESIGN AND INSTALLATION OF A SMART GARAGE SYSTEM FOR CONTROLLING SMALL CITY VEHICLES UTILIZING THE INTERNET OF THINGS AND DATA ANALYTICS

BY

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Abstract

The aim of this research is to develop a proof of concept for a smart garage that would employ Internet of Things (IoT) technologies and deploy its innovative features to automate and control the entry and exit of vehicles. The system identifies any car at the garage gate with the utilization of an ultrasonic sensor and transmits a message to an Arduino Uno microcontroller, which detects the signal and sends the commands to a servo motor to raise or lower the barrier automatically.

Three color LEDs represent the status of the system: green shows entry permission, yellow shows vehicle detection, and red shows readiness. The prototype is also connected to an IoT network for storage of data and monitoring remote performance. The system therefore presents a promising model for applications in parking garage in the future, due to the satisfactory results which proved the fact of high reaction accuracy and low to none manual operations.

Keywords: Internet of Things, smart garage, Arduino, ultrasonic sensor, servo motor, automation, sensing.

Introduction

Automation and intelligent control have emerged as cornerstones of smart city development in recent years. By linking physical devices to the internet and enabling them to autonomously respond to their surroundings, modern systems aim to simplify human life. Parking and garage management are some of the critical applications that have benefited from this development due to congestion and waiting time from public systems entering and leaving. (Allbadi, Y., Shehab, J. N., & Jasim, M. M. 2021) A smart garage means much more than finding parking accessibility.

It also involves securing secure and seamless access and exit for vehicles without human intervention alone. Evidence reports that the integration of Internet of Things (IoT) in smart control systems has significantly improved operation and safety, reduced human error, and increased operational efficiency (Kumar et al., 2021). In a study from the journal Sensors, using sensors in parking garages increases facility management efficiency over 30% with a real-time system of data analytics (Badii et al., 2020). Another work published in IEEE Access demonstrates that using ultrasonic waves for distance detection can be an efficient and precise method of vehicle detection and automated gate management (Anagnostopoulos et al., 2021).

For this example, this investigation provides at least an example of a smart connected garage with Arduino board as the main controller, ultrasonic sensor to detect the vehicle, servo motor for controlling the barrier wall, and LEDs to signal its state. Network connectivity through Internet of Things (IoT) is also adopted for remote monitoring and storage of operational data on a digital dashboard.The system tries to emulate a real world, autonomous garage gate environment, opening and closing automatically as a car passes through.

This lowers the need for manual operation and boosts the speed of entry and exit. This project contributes to the development of low-cost smart technologies that may be scaled up and applied in real-world applications in both public and private garages. (A. Ashari, 2022).

Methodology and Working Method

Research Problem

Most small urban garages rely on manual gate operation, which delays vehicle movement, increases the possibility of errors or collisions with the barrier, and demands a continual human operator. This problem can be overcome by building an intelligent system based on automatic vehicle identification and motor control without human interaction.)Elhoseny et al., 2020).

Research Objectives

1- design and implement a miniature smart garage prototype using an ultrasonic sensor for automatic barrier control.

2- utilize an Arduino microcontroller to control the traffic lights and servo motor.

3- connect the system to the Internet of Things (IoT) to enable remote monitoring and control.

Research Design and Working Method

This study adopts an experimental design approach to develop and evaluate a functional prototype of a smart garage system. The system architecture is composed of both hardware and software components that work together to achieve automated vehicle detection and barrier control. The overall structure and interaction between the main elements of the system are illustrated In the figure below, which presents the detailed research methodology flowchart for the smart garage system.

<u>Components Used:</u>

- Arduino Uno board (main microcontroller).
- HC-SR04 ultrasonic sensor for measuring the distance between the vehicle and the barrier.
- The servo motor is responsible for raising and lowering the beam.
- Three LED lights (red, yellow, green) display the garage status.

Power and connection units + IoT dashboard.

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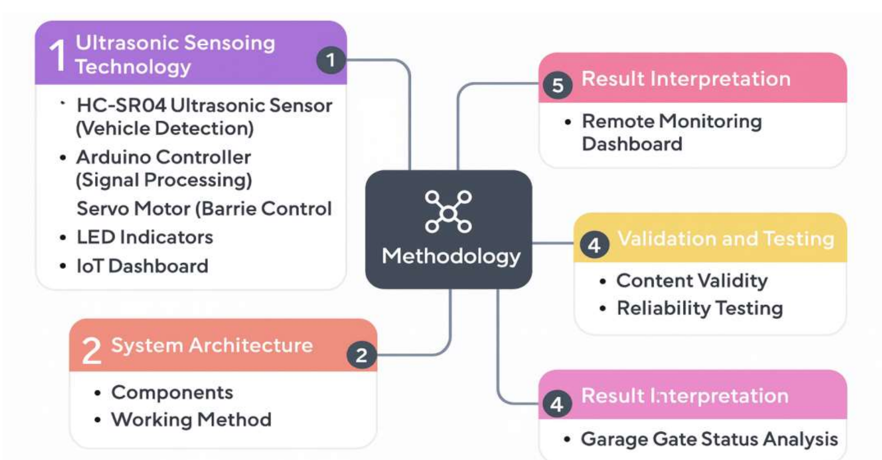


How it works:

1- When no vehicle is in front of the sensor, the distance is significant, and the system displays a red light to indicate that the parking space is closed As in Figure (1) .
2- As a vehicle approaches the sensor, the distance measured by the ultrasonic sensor decreases. The microcontroller then sends a signal to the Arduino, which temporarily activates the yellow light.
3- Once the optimal distance is confirmed, the Arduino sends a signal to the servo motor to raise the barrier, and the light turns green to allow entry As in Figure (2) .
4- After the vehicle passes, the system automatically returns the barrier to its closed position.
5- Data (number of vehicles, opening and closing time, gate status) is sent to an online IoT control board for remote monitoring.

Programming Logic Description: The code programmed on the Arduino relies on measuring the distance value from the sensor.

- If the distance is > 15 cm → (Red light ON).
- If the distance is between 10 and 15 cm → (Yellow light ON, motor preparation).
- If the distance is < 10 cm → (Raise the bar, green light ON).
- After the vehicle passes, the system automatically returns to the initial state.

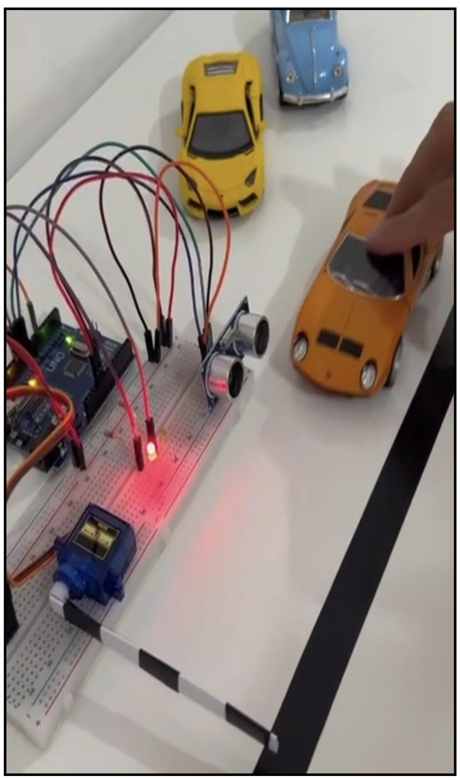


Figure 1

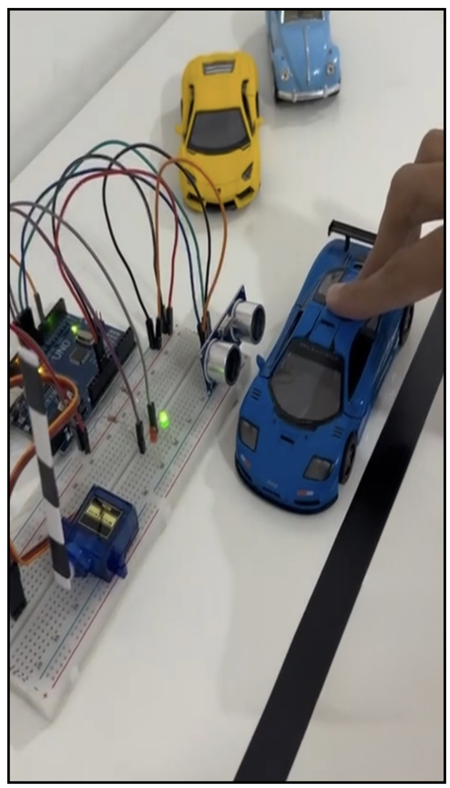
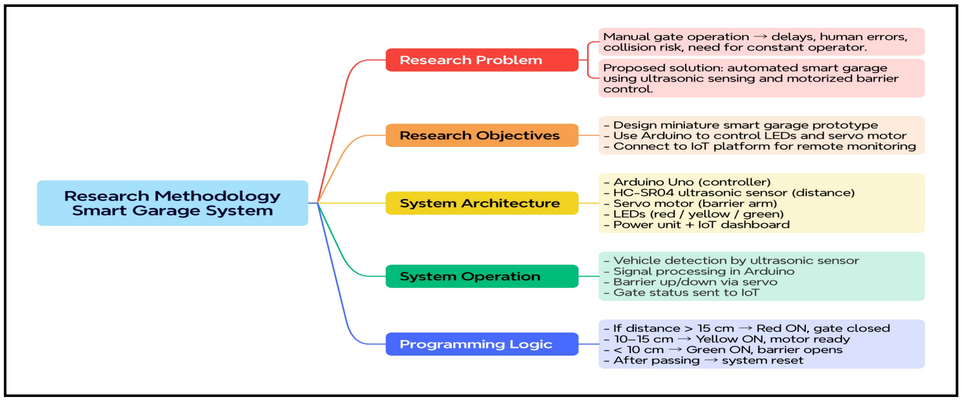


Figure 2



Research Methodology Framework for the Smart Garage System

System Components Description

The smart garage system features a complete set of electronic devices, all of them designed and implemented to be able to perform the task of automatic sensing and control. Microcontroller-based solutions, which can process sensor signals and output devices, were often used in the most recent automation systems (Shehab, 2019; Kurnia & Sie, 2019). Sensors, such as ultrasonic modules, are key in order to properly detect objects and accurately measure distance to make precise control decisions (Najmurrokhman et al., 2019).

Additionally, the communication technologies and interface modules are used to improve the monitoring and system interaction for the better performance and controllability of the system in an IoT-based environment (Prayogo et al., 2019). As a result, each element implemented in this project was chosen based on its validated performance in analogous electronic and automation setups. The specific purpose of each part and the elements of the smart garage system are described in the section that follows.

Arduino Uno

The Arduino Uno microcontroller, which is the primary control component of the smart garage system, is depicted in this figure. After processing the data and receiving signals from the ultrasonic sensor, it transmits control orders to the LED indicators and servo motor.

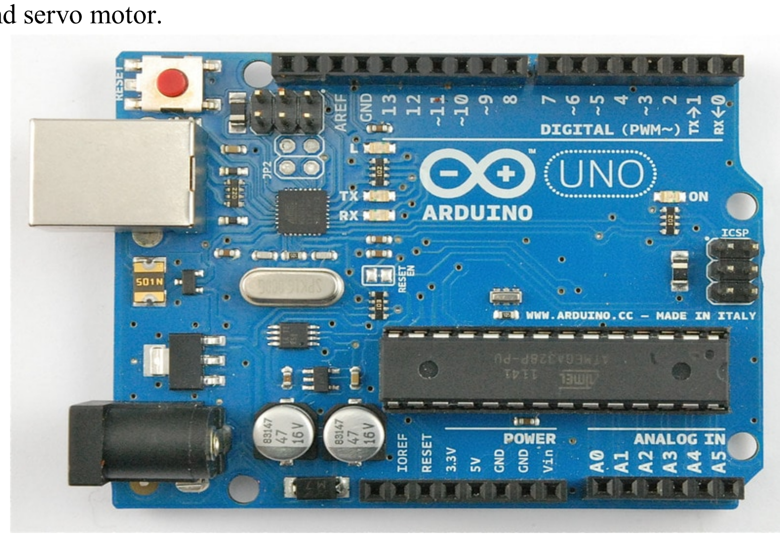


Figure (3) : Arduino Uno microcontroller

Ultrasonic Sensor (HC-SR04)

This image displays the ultrasonic sensor used to identify the presence of a vehicle by measuring the distance between the car and the garage barrier. The Arduino uses the sensor's real-time distance data to make decisions.

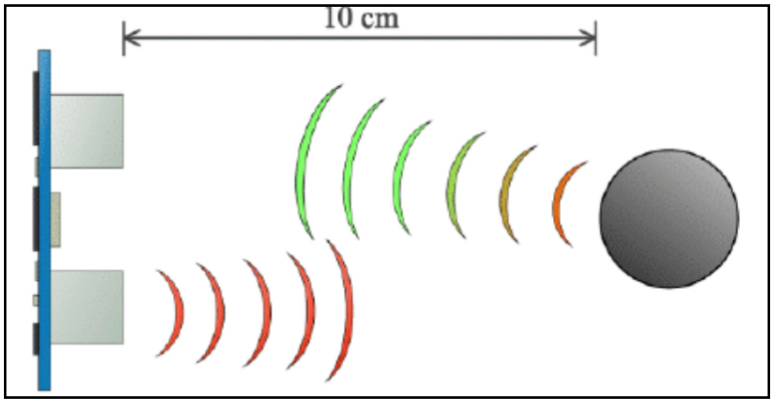


Figure (4): Ultrasonic sensor (HC-SR04)

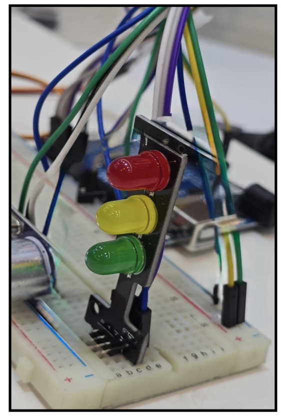


Figure (6): LED indicators

Servo Motor

This figure shows the servo motor responsible for raising and lowering the garage barrier. It operates based on signals received from the Arduino to allow or block vehicle entry.

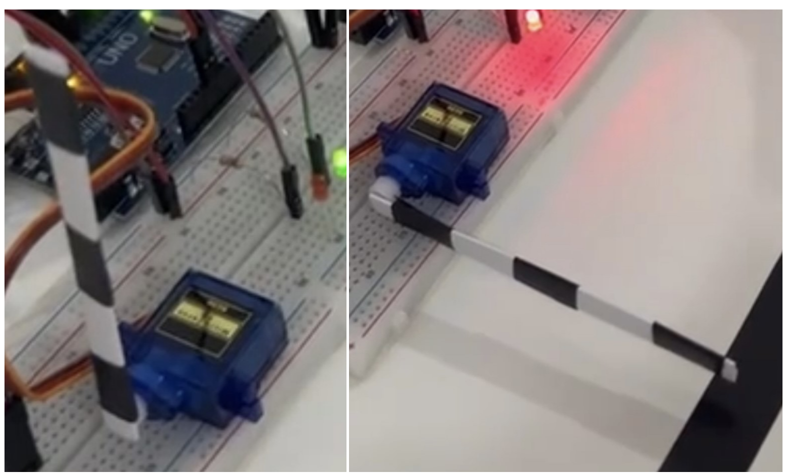


Figure (5): Servo motor

LED Indicators (Red, Yellow, Green).

This information shows the LED lights by which the system status is indicated. Red indicates standby mode, yellow vehicle detection, and green allows vehicle entry.

IoT Dashboard/Control Panel.

A real-time system information including gate and vehicle detection status, as well as system operation, can be viewed via the IoT monitoring interface.

Results and Discussion

Results

The experimental evaluation of the suggested smart garage prototype was undertaken through a series of controlled trials to assess the system's efficacy in recognizing vehicles and activating the barrier mechanism. One of the performance metrics that we considered was the response time, that is the time span between the ultrasonic sensor detecting a vehicle and the servo motor fully opening the barrier.

Table (1) shows the response times measured over eight experimental trials under consistent operational circumstances.

Table (1): Barrier response time for experimental trials

Trial	Distance range (cm)	LED sequence (Red → Yellow → Green)	Barrier action	Response time (s)
١	15–10	Yes	Opened successfully	٠,٨٢
٢	15–10	Yes	Opened successfully	٠,٧٩
٣	15–10	Yes	Opened successfully	٠,٨١
٤	15–10	Yes	Opened successfully	٠,٨٠
٥	15–10	Yes	Opened successfully	٠,٨٣
٦	15–10	Yes	Opened successfully	٠,٧٨
٧	15–10	Yes	Opened successfully	٠,٨٠
٨	15–10	Yes	Opened successfully	٠,٧٩

The recorded response times ranged between 0.78 s and 0.83 s, with an average response time of roughly 0.80 s. All experiments confirmed successful vehicle detection and correct barrier operation, demonstrating consistent system functionality.

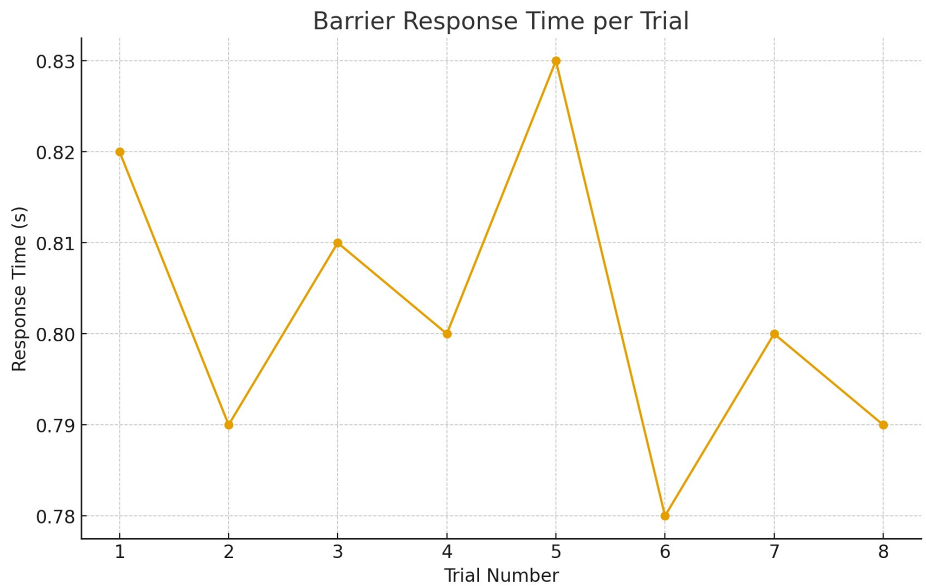


Figure (7): Barrier response time per trial.

This figure (7) shows how the barrier response time varied over the course of eight experimental trials, demonstrating the smart garage system's consistent performance.
This figure (8) displays the relationship between the recorded distance and the system's response time, illustrating that the barrier reacts faster as the vehicle draws closer to the ultrasonic sensor.

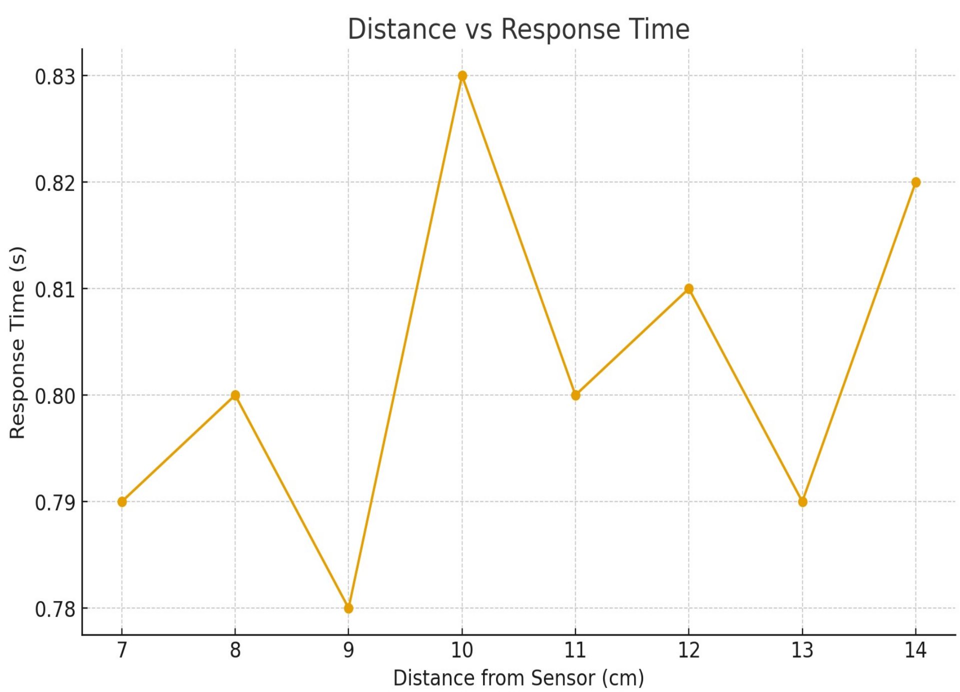


Figure (8): Distance vs Response Time

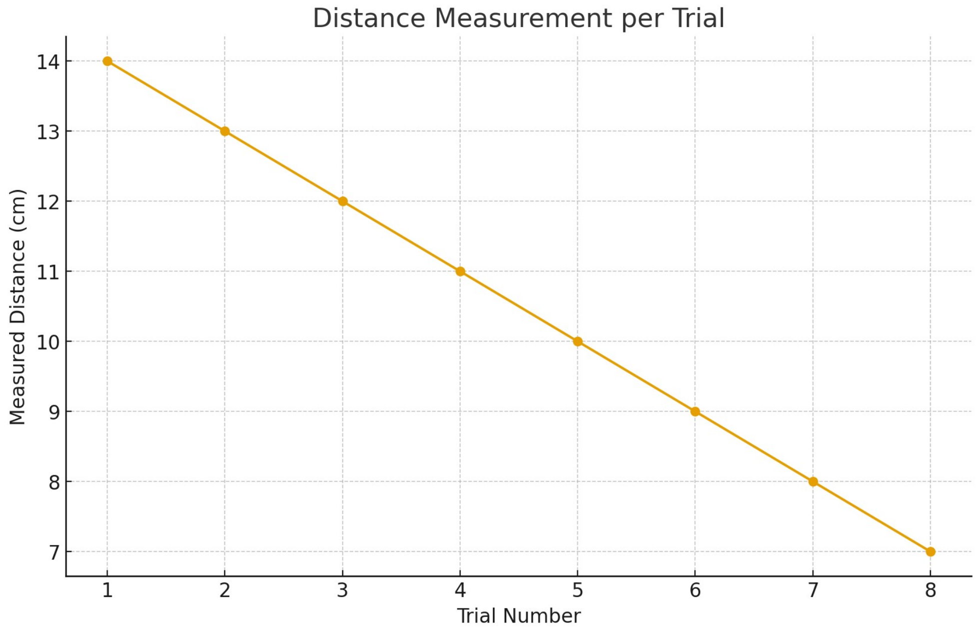


Figure (9): Distance Measurement per Trial

This figure (9) displays the distance values obtained by the ultrasonic sensor throughout each trial, exhibiting consistent and reliable detection performance across all measurements.

Performance behavior of the system in the various tests is shown in three graphs. The variation in response time for eight trials may be seen in Figure (7) showing that the performance does not change much. Figure (8) depicts the correlation between distance measured and the response time of the system demonstrating that the gate responds more quickly as the vehicle approaches the sensor. Figure (9) depicts the distance value measured during each trial, confirming the detection stability of the ultrasonic sensor. As a result of the graphical analysis, the suggested smart garage system functions consistently and efficiently under repeated testing settings.

Discussion

The results of the experiments demonstrate that the suggested smart garage system works in the case of both vehicle detection and effective barrier mechanism control. The average, measured response time of about 0.80 seconds shows that the system is fast enough in actual operation to work in small garages.

The differences in response time with respect to different trials (± 0.03 s from the mean value) show the reliability of control circuitry based on Arduino and the soundness of the HC-SR04 ultrasonic sensor. Such consistency demonstrates that the sensing and actuation is not significantly affected by small changes in the environment or by repetition, which is an indication of system stability.

Furthermore, the optimal sequencing of the LED signal (red to yellow to green) is done for every trial, also proving that the visual feedback system is sufficiently informing drivers about the working condition of the garage. It is also very convenient for driving safety and clarity when entering the vehicle.

The device with IoT connectivity features helps to enhance the system by enabling remote monitoring and data recording which allows the garage owner to continuously measure performance parameters such as response time and usage. The findings suggest that the concept could potentially be scaled to real-world situations with very little improvement, even though prototype size is small. In general, through the proposed smart garage system, our approach has successfully met the research objectives based on the ability to achieve the design elements: providing automated, reliable response to car entering, less reliance on human intervention and increased operational efficiency.

Conclusion

In this project, we built and implemented a small smart garage system that supports the entry and exit control of a smart vehicle using IoT technology. This combination of Arduino, ultrasonic sensor, servo motor, and LED indicators provides accurate vehicle detection and reliable barrier operation with minimal human interaction.

System performance remained stable, and its response times were consistent as a demonstration of the control algorithm and the accuracy of the ultrasonic sensing mechanism. Thus, this system proved clearly to be an effective solution for enhancing operational reliability and reducing manual dependence, and therefore was considered appropriate as a low-cost smart garage automation solution for small-scale parking scenarios.

References

Allbadi, Y., Shehab, J. N., & Jasim, M. M. (2021). The Smart Parking System Using Ultrasonic Control Sensors. IOP Conference Series: Materials Science and Engineering, 1076(1), 012064.

Ashari, A. (2022). Parking System Optimization Based on IoT using Face Recognition and Ultrasonic Sensors. CORE.

Azmi, N. M. F. B., & Ismail, M. B. (2022). Smart Parking System Using IoT with Ultrasonic Sensor. Journal of Engineering Technology, 10(1), 93–97.

EAI/Elsevier. (2022). IoT based smart parking system. EAI Endorsed Transactions on Smart Cities.

Jabbar, M., Khan, A., & Malik, S. (2024). Internet of Things enabled parking management system using Ultrasonic and Magnetic sensors. ScienceDirect.

Kurnia, Y., & Sie, J. L. (2019). Prototype of Warehouse Automation System Using Arduino Mega 2560 Microcontroller Based on Internet of Things. bit-Tech Journal, 1(3), 124–130.

Najmurrokhman, A., Komarudin, U., Annas, A., & Rahim, R. (2019). Design and Realization of a Low Cost Clinometer Based on ADXL345 Sensor, Ultrasonic Sensor, and Android-based Smartphone. Journal of Physics: Conference Series, 1424(1), 012006. IOP Publishing.

Nasim, S., Oussalah, M., & Outila, T. (2022). Smart Parking System Based on IoT Architecture and Intelligent Sensors. SMART 2022.

Prayogo, S. S., Mukhlis, Y., & Yakti, B. K. (2019). The Use and Performance of MQTT and CoAP as Internet of Things Application Protocol using NodeMCU ESP8266. Fourth International Conference on Informatics and Computing (ICIC), IEEE, pp. 1–5.

Rathi, S., Verma, P., & Singh, D. (2025). Automatic Car Parking Toll Gate System Using Arduino and Ultrasonic Sensor. International Journal of Progressive Research in Engineering and Management, Issue 4, April 2025.

ScienceSpace/Embedded. (2023). Smart Car Parking System Using IoT.

Shehab, J. N. (2019). Remote Control using Voice Recognition based on Arduino. Diyala Journal of Engineering Sciences, 12(03), 22–28.