

Motion Activated Automatic Garage Door System

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DOI: <https://dx.doi.org/10.51244/IJRSI.2026.13010053>

Received: 09 January 2026; Accepted: 14 January 2026; Published: 30 January 2026

ABSTRACT

Automatic door systems are designed to reduce manual effort and improve accessibility, safety, and convenience in public and private spaces. This study presents the design and development of a Motion Activated Automatic Garage Door System using an Arduino microcontroller, sensors, and motor control to detect object presence and operate the garage door automatically. Related studies by Orji et al. (2019) and Gupta et al. (2020) demonstrate that ultrasonic and infrared sensors integrated with Arduino platforms provide reliable and low-cost solutions for door automation.

A descriptive–experimental research design was employed to develop and evaluate the proposed system in a controlled environment using a toy as the triggering object. The system performance was assessed in terms of sensor detection accuracy, response time, and reliability of the door opening and closing mechanism. Results indicate that the Arduino-based system responds efficiently to object detection and performs consistent door automation. The study contributes to existing research on embedded systems by demonstrating a simple, affordable, and educational approach to motion-activated garage door automation.

Keywords: Automatic Garage Door System, Arduino, Ultrasonic Sensor, Infrared Sensor, Motion Detection, Embedded Systems, Automation

INTRODUCTION

Automation has become an essential component of modern technology, particularly in improving efficiency, safety, and convenience in daily activities. One common application of automation is the automatic door system, which enables doors to open and close without physical contact. According to Orji et al. (2019), automated doors enhance accessibility for elderly individuals and persons with disabilities while reducing physical effort and direct contact.

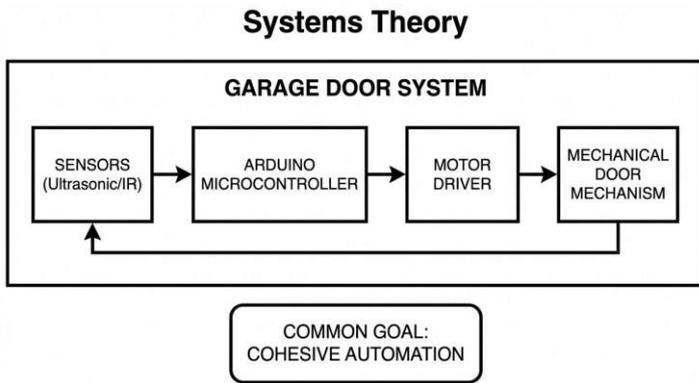
Advancements in microcontroller and sensor technologies have made automatic door systems more affordable and easier to implement. Gupta et al. (2020) noted that the Arduino Uno is widely utilized in automation projects due to its low cost, ease of programming, and flexibility. Sensors such as ultrasonic and infrared sensors are commonly employed to detect the presence of objects, while motors are used to control door movement. These components allow garage doors to operate automatically once motion is detected.

Several studies have focused on improving the reliability and efficiency of motion-based door systems. Kiran (2018) emphasized that sensor-based automation minimizes unnecessary operation and energy loss by activating doors only when needed. These findings highlight the need for continued development of low-cost, reliable, and educational automatic garage door systems.

THEORETICAL FRAMEWORK

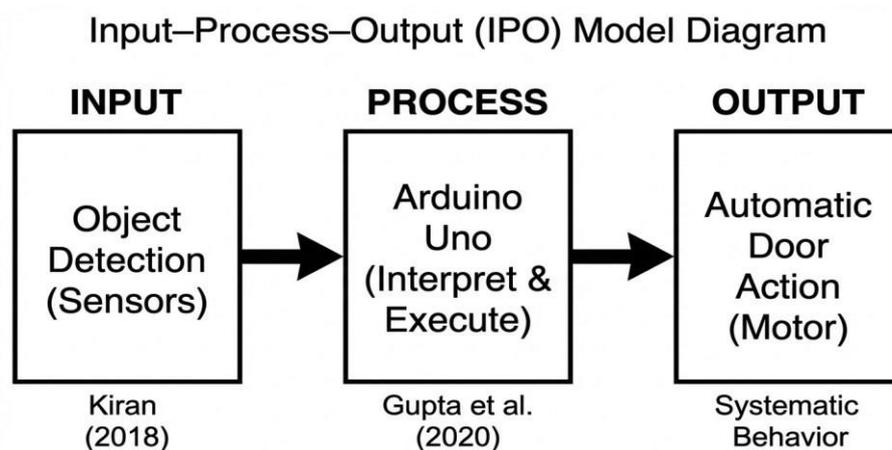
This study is anchored on established theories related to automation, sensor-based detection, and embedded system control. These theories explain the operational behavior of the Motion Activated Automatic Garage Door System and support its design and evaluation.

Figure 1. System Theory



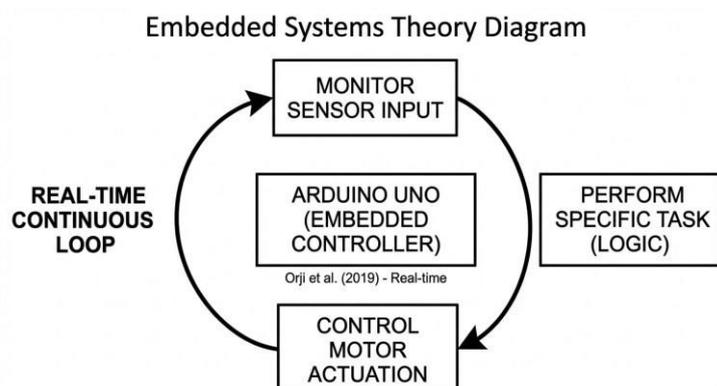
Systems Theory explains that a system is composed of interconnected components working together to achieve a common goal. In this study, the garage door system consists of sensors, an Arduino microcontroller, a motor driver, and a mechanical door mechanism. Proper automation is achieved only when all components function cohesively. This concept aligns with Orji et al. (2019), who emphasized the integration of sensors, controllers, and actuators in door automation systems.

Figure 2. Input–Process–Output (IPO) Model



The Input–Process–Output (IPO) Model describes the functional flow of the system. The input stage involves object detection using ultrasonic or infrared sensors, as supported by Kiran (2018). The process stage includes the Arduino Uno interpreting sensor data and executing control logic, following the approach discussed by Gupta et al. (2020). The output stage is the automatic opening or closing of the garage door through motor actuation. This model ensures systematic and predictable system behavior.

Figure 3. Embedded Systems Theory

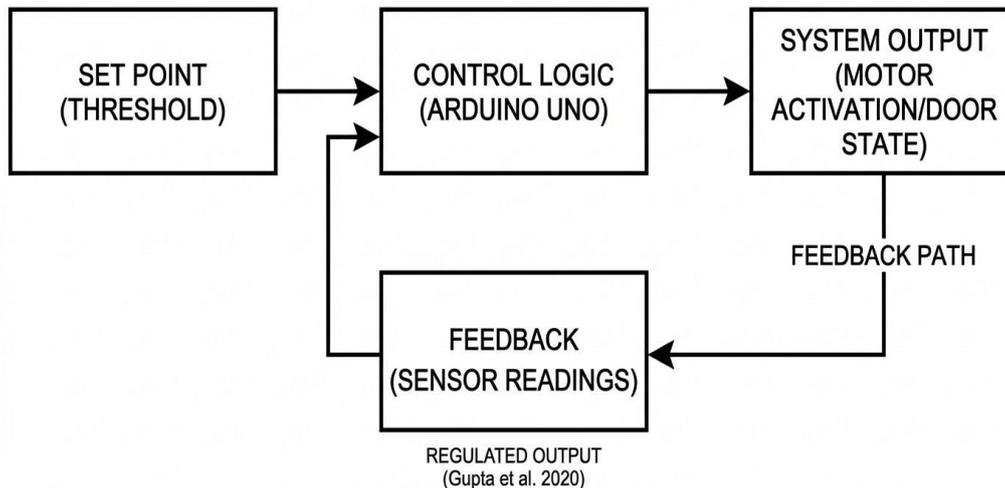


Embedded Systems Theory explains that microcontroller-based systems are designed to perform specific tasks continuously and in real time. In this research, the Arduino Uno functions as an embedded controller that

continuously monitors sensor input and controls the garage door motor. Studies by Orji et al. (2019) demonstrated the suitability of Arduino-based embedded systems for real-time door automation.

Figure 4. Control Systems Theory

Control Systems Theory Diagram



Control Systems Theory focuses on regulating system output based on input feedback. In the proposed system, sensor readings act as feedback that determines whether the garage door should open or remain closed. Threshold-based control logic ensures safe and reliable motor activation. Similar control mechanisms were discussed by Gupta et al. (2020) and Kiran (2018) in automated garage door applications.

Framework Summary

The Motion Activated Automatic Garage Door System is founded on Systems Theory, the IPO Model, Embedded Systems Theory, and Control Systems Theory. These theories collectively explain how the system detects motion, processes sensor data, and controls door movement in a safe and reliable manner.

Related Literature

Research on Arduino-based door automation highlights the effectiveness of ultrasonic and infrared sensors in motion detection. Orji et al. (2019) demonstrated accurate object detection and reliable door control using ultrasonic sensors and servo motors. Gupta et al. (2020) emphasized the cost efficiency and practicality of Arduino-based garage door systems.

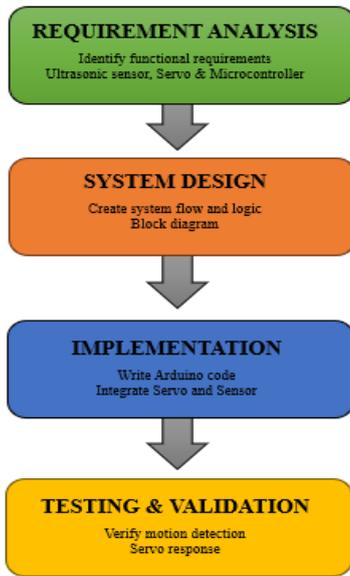
Kiran (2018) discussed motion-activated garage door mechanisms and noted that automation reduces unnecessary operation and energy consumption. Additional studies on object detection using Arduino and ultrasonic sensors support the feasibility of low-cost automation systems for educational and prototype applications.

METHODOLOGY

This study employed a descriptive and experimental research design to develop and evaluate the Motion Activated Automatic Garage Door System. The system was constructed using an Arduino Uno microcontroller, ultrasonic sensor and a motor mechanism to simulate garage door movement. A toy was used as the triggering object to activate the system.

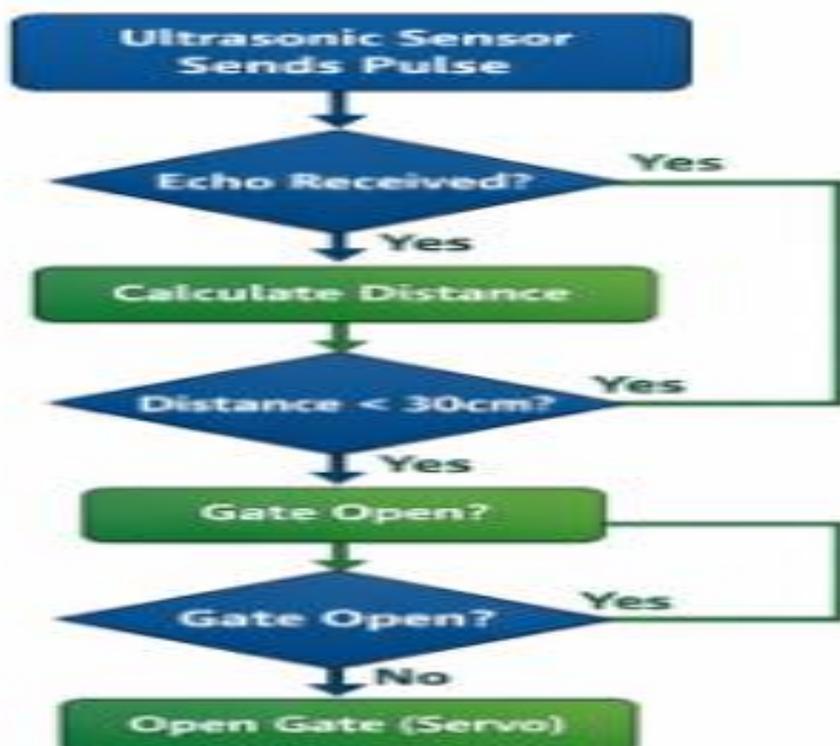
Testing was conducted in a controlled environment by repeatedly passing the object within the sensor's detection range. System performance was evaluated based on sensor detection accuracy, response time, and reliability of the door opening and closing mechanism.

Figure 5. Waterfall Model



The development of the motion detection system followed a structured sequential approach, consisting of four phases: Requirement Analysis, System Design, Implementation, and Testing & Validation. During Requirement Analysis, the functional needs were identified, which included using an ultrasonic sensor to detect objects, a servo motor to perform a mechanical action, and an Arduino microcontroller to process signals and coordinate responses. In the System Design phase, the system flow and logic were planned, detailing how the ultrasonic sensor would measure distance and trigger the servo, followed by the creation of a block diagram to map out hardware connections and control sequences. Implementation involved writing and uploading the Arduino code to read sensor data and control the servo, followed by the physical integration of the ultrasonic sensor and servo motor with the microcontroller. Finally, Testing & Validation were performed to verify that motion detection was accurate, the servo responded appropriately to detected objects, and the overall system operated reliably under real-world conditions. The core operation of the system can be summarized in the following pseudo-code logic: Initialize servo and ultrasonic sensor, Loop continuously: Measure distance using ultrasonic sensor, If distance < threshold: Move servo to activated position, Else: Return servo to default position.

Figure 6. Flow Chart

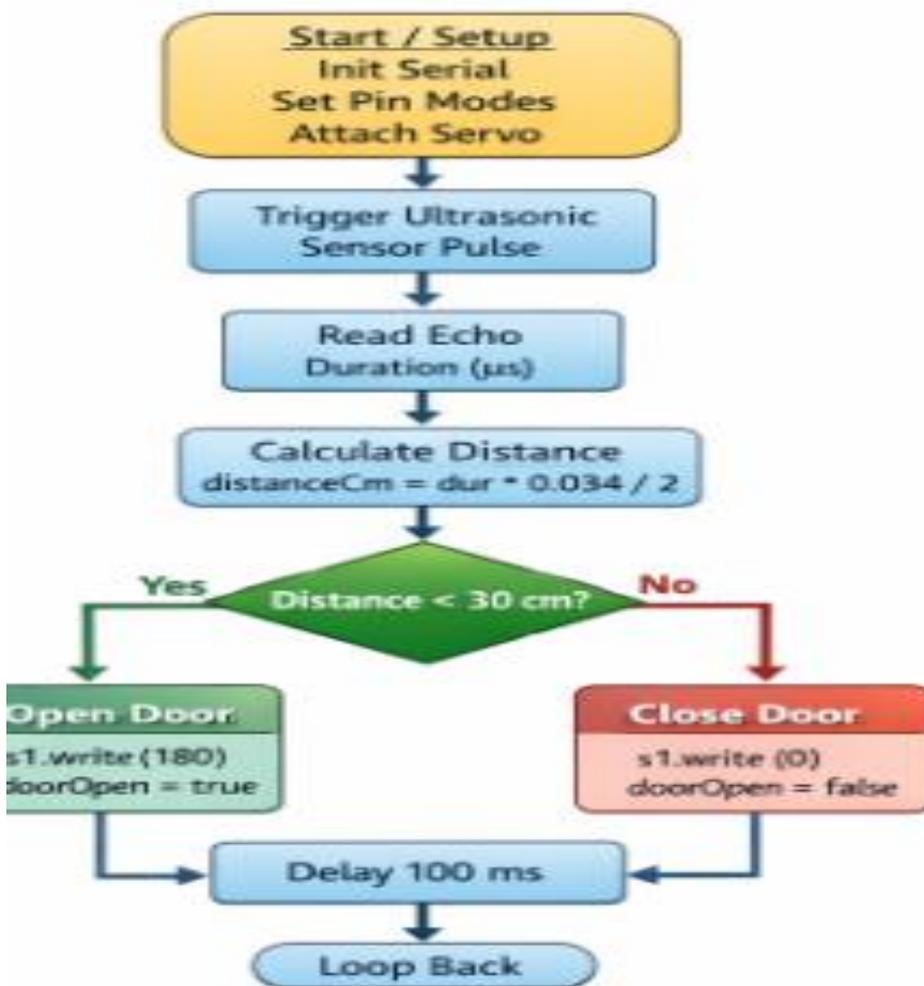


This diagram represents the step-by-step execution of the Arduino program that controls the garage gate using an ultrasonic sensor and a servo motor. It starts with the setup phase, where essential hardware components are initialized: the Arduino serial communication is activated for debugging, the ultrasonic sensor pins are configured as input/output, and the servo motor is attached to its designated pin.

Once setup is complete, the system continuously runs in a loop. It triggers the ultrasonic sensor to emit a pulse, waits for the echo, and measures the time it takes for the sound wave to bounce back from an object. This time is then converted into a distance in centimeters, representing how far an object is from the sensor.

The diagram then shows a decision-making process: if an object is detected within 30 cm and the gate is currently closed, the servo rotates to 180° to open the gate; if no object is detected and the gate is open, the servo rotates back to 0° to close it. A short delay ensures the loop doesn't overload the system.

Figure 7. System Logic Flow Chart



This diagram focuses on the core interaction between the ultrasonic sensor and the servo motor, which is the heart of the automated garage gate system. It begins with the ultrasonic sensor sending a pulse, which travels through the air and reflects off nearby objects. When the echo is received, the system calculates the distance to the object.

The flowchart emphasizes the decision-making process: if the object is closer than the defined threshold (30 cm), the system checks whether the gate is already open. If not, it commands the servo to open the gate. Conversely, if the object is no longer within the threshold distance, the system checks if the gate is open and, if so, commands the servo to close it. This creates a responsive, real-time control loop where the gate reacts automatically to object detection.

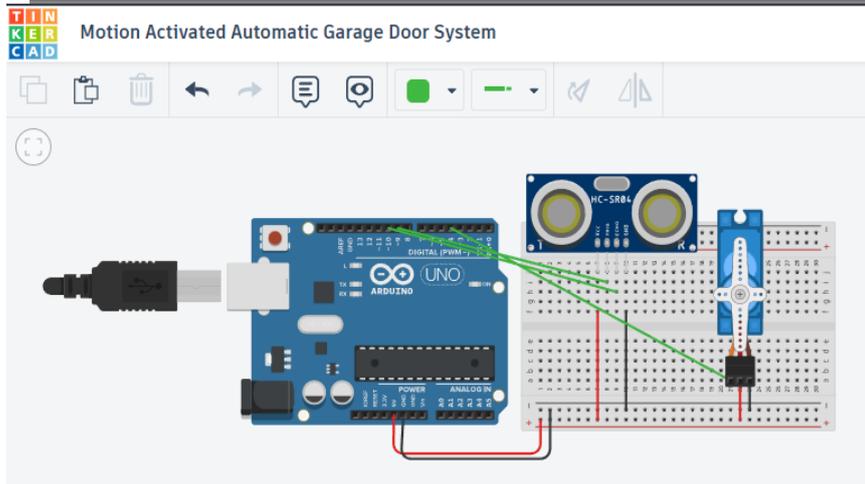


Figure 8. Tinkercad Circuit

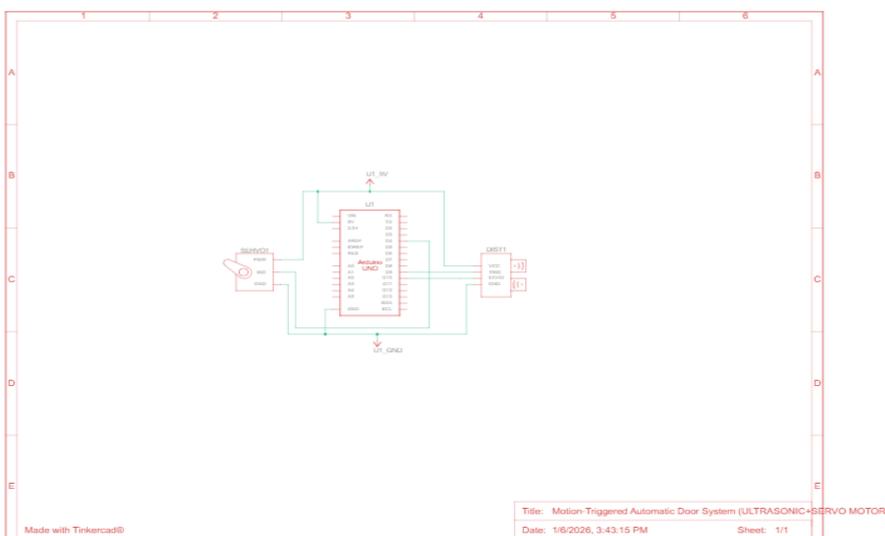


Figure 9. Schematic Diagram

It shows the complete schematic wiring of the Motion-Activated Automatic Garage Door System, illustrating how each electronic component is connected to the Arduino Uno to achieve automatic opening and closing of the garage door. The ultrasonic sensor is interfaced with the Arduino through its trigger and echo pins, allowing the system to detect the presence and distance of a vehicle or person approaching the garage. The Arduino processes this distance information and determines when motion is within the programmed range. A servo motor is connected to a PWM-enabled digital pin and serves as the actuator that physically opens and closes the garage door by rotating to specific angles. All components share common power and ground connections to ensure reliable operation. This schematic demonstrates how the microcontroller, sensor, and motor work together as an integrated system that enables hands-free, motion-activated control of the garage door.

RESULTS & DISCUSSION

Testing Procedures

The system was tested through practical observation. Objects such as a hand and a toy car were placed in front of the ultrasonic sensor to determine whether the sensor could detect their presence and trigger the servo motor. The primary goal of the testing was to verify if the system could detect nearby objects and automatically open the door mechanism.

When an object was detected, the servo motor rotated to simulate door opening. Once the object was removed, the servo returned to its original position. The testing focused on system functionality and response rather than numerical distance accuracy.

Observations, Analysis & Interpretation

The system successfully detected nearby objects such as a hand and a toy car and activated the servo motor to open the door mechanism. In most trials, the servo motor rotated smoothly to the programmed angle, demonstrating proper coordination between the ultrasonic sensor and the servo.

However, occasional glitches were observed where the servo motor rotated faster and to a shorter angle than expected. This behavior is likely due to unstable power supply, minor fluctuations in ultrasonic readings, or electrical noise affecting the servo control signal. Despite these intermittent issues, the overall system performance was reliable and achieved its intended function.

Problems Encountered & Solutions

During the development and testing of the system, several issues were encountered that affected its performance. One major problem was loose wiring, which caused unstable behavior such as inconsistent detection and erratic servo movement. This was resolved by securing all connections properly and ensuring common grounding between components, which significantly improved overall system stability. Another challenge was “ghost rotation” and servo glitching, where the servo motor sometimes moved unexpectedly, rotated faster than intended, or failed to reach the full angle even when the object position remained unchanged. This issue was mitigated by stabilizing the wiring, confirming proper grounding, and implementing logic conditions in the code to prevent repeated servo commands. After these adjustments, the occurrence of servo glitches was greatly reduced and did not noticeably affect system performance.

Requirements

The functional requirements of the Motion Activated Automatic Garage Door System focus on its automated control and response to object detection. The system continuously monitors its surroundings using an ultrasonic sensor to detect nearby objects in real time. When an object is detected within the predefined threshold distance of 30 cm, the system automatically activates the servo motor to open the garage door. If no object is detected within this range, the system commands the servo motor to return to its default position, effectively closing the door. To ensure proper operation, logic conditions are implemented to prevent repeated or unnecessary servo commands, reducing the occurrence of erratic movements. All sensing, decision-making, and control processes are managed by the Arduino Uno, ensuring coordinated interaction between the ultrasonic sensor and the servo motor.

The non-functional requirements define the system’s performance, reliability, and stability. The system is designed to provide real-time responsiveness, allowing the garage door to react immediately to changes in object presence. Reliability is emphasized through stable wiring connections, proper grounding, and sufficient power supply to minimize servo glitches and unintended movements. The servo motor is expected to operate smoothly and consistently, reaching the programmed angles without delay or overshoot. Measurement reliability is maintained by ensuring consistent ultrasonic sensor readings within the operating range. Overall, the system prioritizes safe, stable, and efficient operation, making it suitable for low-cost automation and educational embedded system applications.

Table 1. Variables and Conditions of the Motion Activated Automatic Garage Door System

Variable / Component	Type (Input / Output)	Parameter Measured / Controlled	Condition or Range	System Response / Action
Ultrasonic Sensor (HC-SR04)	Input	Distance to object	0–30 cm / > 30 cm	Detects object presence and sends distance data to the controller
Servo Motor	Output	Angular position	0° (Closed) / 180° (Open)	Opens the garage door when an object is detected and closes

				it when no object is present
Arduino Uno	Controller	Control logic and signal generation	Continuous operation	Processes sensor input and controls servo movement based on programmed conditions
9V Power Supply	Input	Operating voltage	9V DC	Provides electrical power to the Arduino and connected components

Table 2. Variables and Conditions of the Motion Activated Automatic Garage Door System

Test #	Input Condition	Observed Output	Expected Output	Pass/ Fail	Remarks / Behavior Explanation
1	No object within sensor range (>30 cm)	Servo remains at 0°	Door remains closed	Pass	Normal idle state; system correctly detects no motion
2	Hand placed within 30 cm	Servo rotates to 180°	Door opens automatically	Pass	Proper object detection and servo response
3	Hand removed from sensor range	Servo returns to 0°	Door closes automatically	Pass	Correct closing behavior after object removal
4	Toy car placed within 30 cm	Servo opens door	Door opens smoothly	Pass	System accurately detects solid object
5	Continuous object presence within 30 cm	Servo holds open position	Door remains open	Pass	Logic prevents repeated servo commands
6	Object rapidly moved in and out of range	Servo opens and closes quickly	Controlled open/close motion	Pass	System responds in real time without freezing
7	Loose wiring on servo signal line	Servo moves erratically	Stable servo movement	Fail	Loose wiring caused unstable signals and inconsistent servo motion
8	Stable wiring but fluctuating power	Servo rotates faster, stops early	Full 180° rotation	Fail	Servo glitching due to power instability and voltage drop

9	Object stationary but repeated loop execution	Servo twitches slightly	Servo should remain still	Fail	Ghost rotation caused by repeated control signals in loop
10	Wiring secured and logic condition added	Servo moves smoothly	Stable and accurate movement	Pass	Loose wiring and ghost rotation minimized through grounding and logic fixes

The results confirm that the Motion Activated Automatic Garage Door System effectively performs automated opening and closing by prioritizing sensor-based decision logic over manual control. The consistent activation of the servo motor only when an object is detected within the 30 cm threshold demonstrates proper implementation of the programmed conditions. The system’s real-time response to object presence and removal aligns with basic Control Systems Theory, where continuous sensing and feedback enable stable and responsive operation. Although issues such as loose wiring, ghost rotation, and servo glitching were observed during initial testing, these did not undermine the core functionality of the system and were largely resolved through improved wiring, proper grounding, and refined logic conditions executed by the Arduino Uno. These results are consistent with related studies on ultrasonic sensor-based automation and microcontroller-controlled actuators. Furthermore, the simplicity of the hardware setup and program logic makes the system well-suited for educational applications, allowing students to understand sensor integration, feedback control, and embedded system behavior while still demonstrating practical automation suitable for small-scale residential use.

CONCLUSION

This study successfully designed and developed a Motion Activated Automatic Garage Door System using an Arduino Uno, an ultrasonic sensor, and a servo motor. The system can detect nearby objects and automatically open and close the garage door without manual operation. Based on the testing results in a controlled environment, the system showed reliable performance in detecting motion and moving the door correctly. The proper coordination between the sensor, the Arduino microcontroller, and the servo motor shows that Arduinobased systems are effective for simple automation projects.

During testing, small problems such as servo glitches and unstable movement were observed. These issues were caused by loose wiring, power instability, and repeated control signals. The problems were reduced by fixing the wiring, ensuring proper grounding, and improving the program logic. Overall, the project met its objectives and proved that a low-cost motion-activated garage door system can be built successfully. This study is also useful for students because it helps them understand sensor integration, basic control systems, and embedded system design through hands-on learning.

RECOMMENDATIONS

For future improvements, researchers may consider using a more stable and dedicated power supply for the servo motor to minimize glitches and unintended movements. The system’s detection accuracy and reliability can be further enhanced by integrating additional sensors, such as infrared or PIR sensors, alongside the existing ultrasonic sensor. Testing the system under real-world conditions using an actual garage door mechanism, rather than a simulated or scaled model, would provide a better evaluation of performance and durability. Safety features, including obstacle detection during door closing and emergency stop mechanisms, may also be incorporated to prevent accidents and equipment damage. Moreover, implementing wireless control or monitoring capabilities, such as mobile application integration or IoT connectivity, could improve user convenience and system functionality. Finally, further studies may focus on optimizing the control algorithm to reduce response time and ensure smoother servo movement.

ACKNOWLEDGEMENT

The researchers would like to express their sincere appreciation to Prof. Engr. Meshelle N. Fabro, who was assigned to oversee this project. Her role in setting the project requirements and ensuring its proper completion contributed to the successful conduct of this study.

The researchers also extend their gratitude to the Computer Engineering Department of Eulogio "Amang" Rodriguez Institute of Science and Technology (EARIST) for providing the academic support, technical instruction, and resources necessary for the completion of this project.

Heartfelt thanks are extended to the researchers' families, relatives, classmates, and peers for their encouragement and support throughout the research process.

The researchers also acknowledge the individuals who, in various ways, contributed to the refinement and improvement of this study.

Above all, the researchers give thanks to God Almighty for the strength and perseverance granted to complete this work.

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