Distance-Based Object Detection System for Parking Assistance

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I. Introduction

Parking in tight spaces, including residential driveways or parking lots, can result in small collisions as a consequence of drivers misjudging the distances between their cars and surrounding objects. Even though there are commercial parking assistance systems, such as camera- or radar-based systems and installing them is either costly or difficult, particularly in older vehicles. Furthermore, a lot of drivers don't require the intricacy of camera-based systems or the long-range detection provided by radar. Using an Ultrasonic Ranging Module (HC-SR04) and an Arduino Nano 33 IoT to measure distances and notify drivers in real-time, this project offers an affordable and simple-to-implement solution that makes use of cloud-based technologies for data logging and display.

This system solves the demand for an accessible, cost-effective parking assistance solution that offers real-time monitoring, data logging, and alerts when vehicles approach obstacles too closely by using IoT technology.

II. Literature Review

There are several different parking assistance systems on the market, ranging from basic ultrasonic sensors to sophisticated camera and radar-based setups. We analyse the advantages and disadvantages of each solution here.

a) **Camera-Based Systems**

With the use of one or more cameras installed on the car, camera-based parking assistance systems capture live video of the environment and give drivers visual feedback in real time. These technologies provide precise, detailed visuals that make it easier for drivers to identify obstructions and manoeuvre in small places. Advanced vision-based systems that combine machine learning and computer vision have been created recently to improve tracking, depth estimation, and object detection.

For instance, the authors of the paper "Vision-Based Parking Assist System" [1] go over how camera-based systems can be used to identify obstacles and help drivers park. These systems use augmented reality overlays to provide extra guidance in certain situations, and they rely on image processing algorithms to produce a clear visual representation for the driver. Camera integration makes it possible to accurately identify objects in the path of the car and reduces the risk of crashes.

Advantages of these systems include:
High accuracy: Direct visual feeds from camera-based technologies enable drivers to identify obstacles with extreme precision.
Visual feedback: Real-time object visibility helps drivers manoeuvre through confined places and avoid obstructions.

However, the disadvantages include:
High cost: Installing camera-based systems can be costly, particularly for older cars that do not have the required gear installed from the factory.
Complex installation: Expert installation is frequently necessary due to the need for accurate calibration and setup, which are necessary to guarantee the system operates as intended.
Environmental factors: Weather-related factors, such as rain or fog, can have an impact on camera-based systems by reducing visibility.
Although camera-based systems are more advanced in terms of object identification and visual input, older car owners and those seeking more economical solutions may find it more difficult to install these systems. This emphasises the need for less expensive substitutes, such as ultrasonic sensors, which, despite being less accurate, function adequately in a variety of parking situations for a small portion of the price.

b) **Radar-Based Systems**

Radar-based parking assistance systems use radar sensors to determine the distance between a car and an obstacle. These systems are well-known for their great precision and adaptability to a wide range of environmental conditions. Radar sensors generate radio waves and monitor how long it takes for them to reflect off close objects. This technology is especially beneficial for delivering distance measurements with more precision than ultrasonic sensors.

According to the paper "Millimetre Wave Radar Technology for Autonomous Driving" [2], radar systems are commonly utilised in the automotive industry for applications such as obstacle detection, speed monitoring, and parking assistance. Radar's ability to perform in a variety of environmental circumstances, including rain, fog, and low light, makes it a dependable choice for parking assistance. Radar systems can identify obstacles over short and long distances, and they are less sensitive to environmental noise than camera-based systems.

Radar-based systems offer the following advantages:
High accuracy: Radar can correctly measure the distance to obstacles in real time, even in bad weather.
Long-range detection: Radar sensors can detect obstructions from both short and long distances, making them useful in a variety of parking conditions.
Environmental resilience: Unlike cameras, radar is unaffected by sunlight or weather, making it a more dependable solution in a variety of scenarios.

However, there are some downsides.
High cost: Radar systems are often expensive, limiting their use to luxury automobiles.
Complex installation: Installing radar systems requires professional skills because it entails putting sensors in exact positions and configuring them to perform properly.

While radar systems outperform in terms of accuracy and environmental resilience, their high cost and installation complexity make them unsuitable for everyday customers seeking economical parking assistance options. Ultrasonic-based systems, such as the one presented in this project, provide a simpler, more cost-effective solution.

c) **Ultrasonic-Based Systems**

Ultrasonic sensors are commonly employed in parking assistance systems due to their low cost and ease of usage. These sensors operate by producing sound waves and detecting how long it takes for the waves to bounce back from an object, allowing them to compute the distance between the vehicle and obstacles. They are useful for short-range applications like parking, which require precise distance measurements at a cheap cost.

In their study "Ultrasonic Sensors for Object Detection" [3], the authors examine the use of ultrasonic sensors in automotive applications, emphasising their ability to identify things at close range. Ultrasonic sensors are easier to install and less expensive than other types of sensors, such as radar or camera systems. However, they have limited range and precision, especially when detecting small or soft things. Furthermore, external conditions such as temperature and wind can impair their efficiency.

The benefits of ultrasonic systems include:
Low cost: Ultrasonic sensors are inexpensive and simple to install, making them suitable for a wide range of applications, including DIY projects.
Simplicity: These sensors are easy to install and require little calibration or technical skill.
Short-range accuracy: They are well-suited for parking applications due to their high short-range detection performance.

The biggest disadvantages are:
Ultrasonic sensors have a limited range, often up to a few meters, making them unsuitable for long-range detection.
Environmental sensitivity: Temperature, wind, and surface material can all influence the accuracy of the sensor's measurements.

Despite these limitations, ultrasonic systems are a more cost-effective alternative to radar or camera systems, particularly for parking assistance.

Innovative Aspect: Current ultrasonic implementations typically lack cloud integration, real-time alerts, and data logging capabilities; the proposed approach fills these shortcomings. This solution combines the HC-SR04 ultrasonic sensor with cloud technologies to enable real-time monitoring, data logging, and alarm capabilities. The technology allows vehicles to be equipped with a low-cost, easy-to-install parking assistance system that gives real-time feedback and historical data recording via Arduino Cloud. This technique distinguishes itself by providing advanced capabilities normally found in more expensive systems, thereby making parking assistance more accessible and affordable.

III. METHODS

The design and implementation of the proposed distance-based object detection system are described in this section, with particular focus paid to the creative combination of the ultrasonic sensor and cloud-based data logging.

a) **Data Sources and Destinations**

Ultrasonic sensor HC-SR04 is the data source.
Data Destination: Real-time monitoring and historical data logging via the Arduino Cloud dashboard.

b) **Data Types**
Data Type: The vehicle's distance from surrounding obstructions, expressed in centimetres.
Frequency: Every second, data is recorded and sent.

c) **Data Capture Protocol**
The sound wave's time when it hits and return from an object is measured by the HC-SR04 Ultrasonic Sensor. The data is processed by the Arduino Nano 33 IoT using the following formula:

$$Distance\ (cm) = \frac{Time\ (\mu s) \times 0.0343}{2}$$

This data is transmitted in real-time to the Arduino Cloud for display and storage.

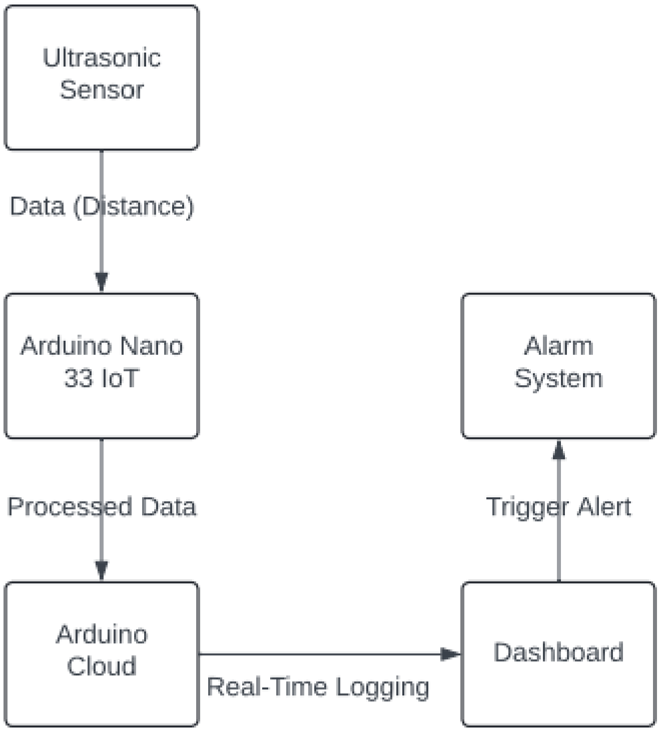
d) **Data Logging and Storage**
The Arduino Cloud receives the distance data continuously and displays it in real time on a dashboard. Users can examine parking sessions and determine the frequency with which the car approaches obstacles too closely by looking at the data that is saved in the cloud for further analysis.

e) **Types of Storage: Cloud**
Cloud Storage: The Arduino Cloud stores all distance data, allowing for long-term logging for data analysis and remote access.

f) **Data Dashboard for Monitoring**
The distance data is shown in real time on an Arduino Cloud dashboard that may be customised. While parking, users can keep an eye out for obstacles and review past data logs to evaluate parking performance over time.

g) **Data Analytics and Alerts**
Alerts: When the distance between an obstacle and the car is less than a certain threshold, such as 20 cm, the system raises an alert. It is possible to add email or SMS notifications to these alerts.
Pattern Identification: Analytics can be integrated to identify trends in user behaviour, such as regularly approaching obstacles too closely, which can assist drivers in developing better parking practices.

h) **Flowchart and System Design**



IV. RESULTS (SIMULATED)

Distance Measurement Accuracy

The high accuracy distance measurement of the HC-SR04 Ultrasonic Sensor is maintained with an error margin of about ±2 cm. The sensor demonstrated consistent results in detecting obstacles at different distances throughout simulated tests. For instance, the sensor gave precise readings within the anticipated error range when an object was positioned at a distance of 50 cm.

Real-Time Data Transfer

The sensor's recorded data was successfully sent in real time to the Arduino Cloud. Tests using simulated data revealed that the cloud dashboard's distance data updated in less than a second after the measurement was made. Users may effectively monitor their vehicle's surroundings thanks to this real-time capabilities.

Setting Off Alerts

When the distance between the car and an obstruction is less than a preset threshold, such as 20 cm, the system is intended to emit an alert. The alert was successfully triggered during the simulated tests when the object approached the sensor by more than 20 cm. The linked alarm system and the cloud dashboard both showed this alert.

Example of Simulated Data

The simulated data in the table below shows how the system operates over time, with precise distance readings and alerts that sound when the threshold is exceeded.

Time (s)	Distance (cm)	Alert Triggered?
0	100	No
1	90	No
2	50	No
3	20	Yes
4	10	Yes

Sample Dashboard Output

The system's dashboard provides real-time updates on the measured distance. When the threshold is crossed, the dashboard shows an alert notification. The simulation included the following steps:

At 20 cm, an alert was issued, instructing the vehicle to stop.
At 10 cm, the alarm remained active, ensuring the driver was aware of the obstacle's vicinity.

V. DISCUSSIONS

By combining an Arduino Cloud with an HC-SR04 Ultrasonic Sensor, this project provides a useful and affordable substitute for current parking assistance systems. The solution is affordable and simple enough for car owners who cannot afford expensive camera or radar-based systems.

a) **Advantages**

Low-cost solution: A wide range of users can access this system thanks to its reasonably priced components.
Cloud-based: Traditional ultrasonic sensors are not the only way the system is improved by real-time data logging and monitoring.
Easy Installation: Professional experience is not required for the system's installation, as it is designed to be simple..

b) **Disadvantages**

Range: Because of its 4 metre maximum range, the sensor might not be appropriate in all parking situations.
Sensitivity to Environment: Wind and temperature can have an impact on how accurate ultrasonic measurements are.

VI. FUTURE WORK

The functionality of the system can be improved in a number of ways, including:
Integration of GSM Module: By including a GSM module, the system will be able to notify users via SMS or email when the vehicle is approaching an obstacle.
Several Sensors: The system can be upgraded to include 360 degrees of coverage by adding more ultrasonic sensors to cover the sides of the car.
Environmental Calibration: The accuracy of distance measurements can be increased by using temperature sensors to account for environmental conditions that may alter ultrasonic readings.

VII. Budget and Development Plan

Hardware Costs

Item	Price (AUD)	Vendor
Arduino Nano 33 IoT	$44.60	Core Electronics
HC-SR04 Ultrasonic Sensor	$1.95	Core Electronics
Jumper Wires (M/M)	$3.95	Core Electronics
Solderless Breadboard	$2.05	Core Electronics
TOTAL COST	$52.55	

Software Costs

Item	Specification	Price (AUD)
Arduino IDE	Open-source development environment	Free
Arduino Cloud	Free tier, real-time monitoring, dashboard setup	Free
Python	Python environment for backend tasks, data processing	Free
TOTAL COST		$0.00

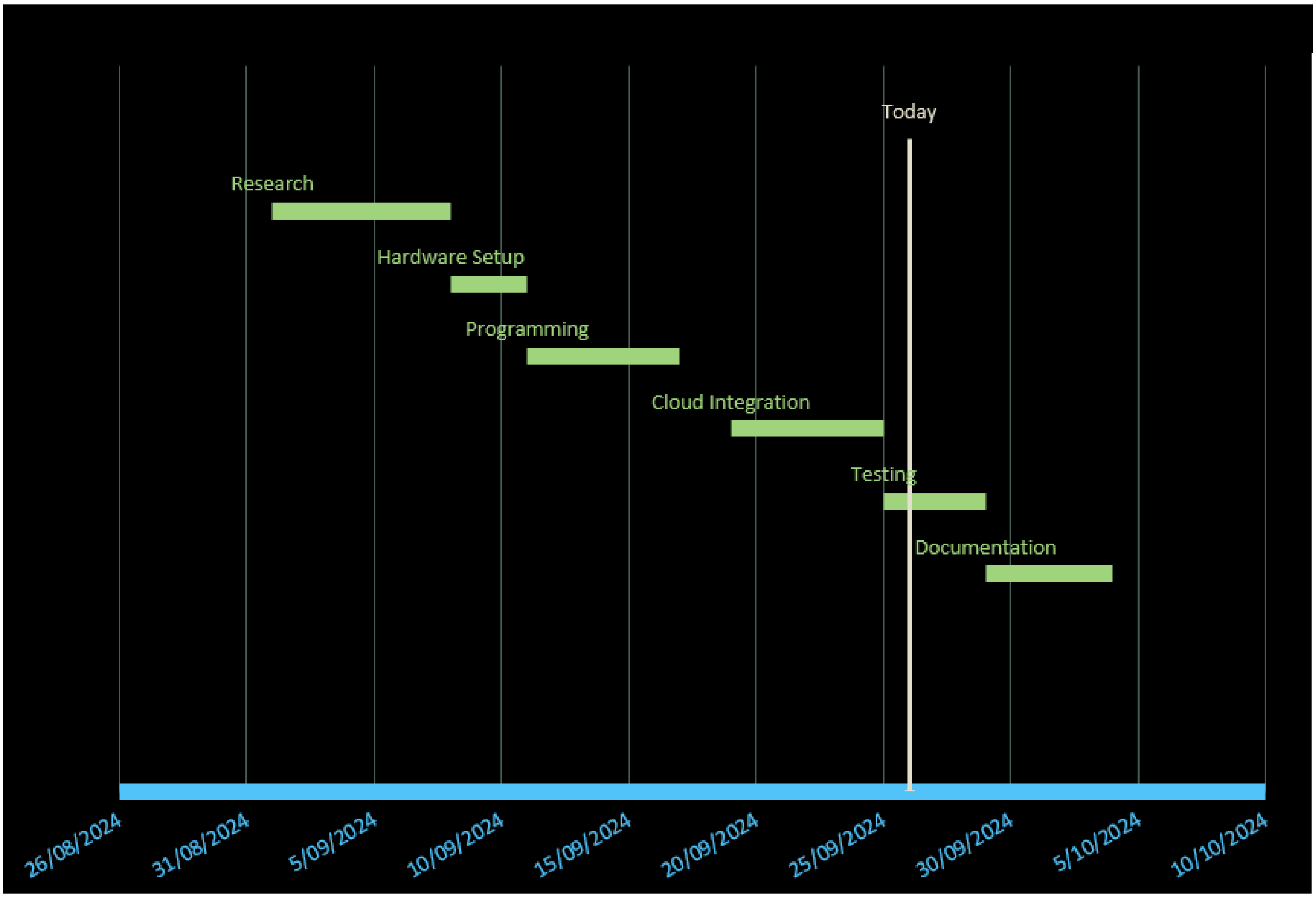
Programming Requirements

- Microcontroller (Arduino Nano 33 IoT):

The Arduino Nano 33 IoT requires about 3 hours of programming. This entails collecting data from the HC-SR04 Ultrasonic Sensor, analysing it, and transmitting it to both the Arduino Cloud and the Python script for real-time display and updates.
The programming will include initialising the sensor, analysing distance data, and ensuring that the data is consistently delivered to the cloud and Python for real-time monitoring.

Cloud Integration:
It takes approximately two hours to integrate the Arduino Nano with Arduino Cloud. This includes configuring cloud variables for distance data and building a dashboard for real-time monitoring. The dashboard automatically changes based on sensor data sent over the cloud

Gantt Chart



Research (6 hours)
The research step entailed obtaining information regarding the HC-SR04 Ultrasonic Sensor, the Arduino Nano 33 IoT, and various cloud integration techniques. This phase took 6 hours across a few days and was required to lay a firm foundation for the remainder of the project.

Hardware Setup (1 Hour):
The hardware setup involved attaching the HC-SR04 sensor to the Arduino Nano 33 IoT. Given my previous experience with similar setups, I finished this assignment in an efficient 1 hour. It included configuring the hardware and ensuring that the sensor readings were correct.

Programming (3 hours):
The programming part entails building code to collect distance data from the sensor and transmit it to the cloud. Based on my skill set and experience, I estimate that this assignment will take 3 hours, including time for debugging and testing the code.

Cloud Integration (2 hours):
Cloud integration will entail configuring the Arduino Cloud for real-time data logging. Using pre-built libraries and dashboards, this procedure should take two hours to complete, ensuring that the system can send and display data on a cloud dashboard.

Testing (4 hours):
Testing will entail ensuring that the system operates as planned under various scenarios. This involves ensuring that the distance measurement is precise, the data is correctly provided, and alerts are generated as needed. Testing will last a total of four hours.

Documentation (2 hours):
After the testing phase, I plan to recount the entire process, including the outcomes and any lessons learnt. This activity is expected to take two hours to assemble all required information and prepare the final project report.

Justification of the Plan:

Man-hours: The man-hours were carefully estimated based on the complexity of each task and my familiarity with the tools and technology used. Given my prior experience with Arduino and cloud systems, the time allotted to each process is sufficient to ensure quality while remaining efficient.
Skill Level: Because of my knowledge with Arduino programming, hardware setup, and cloud integration, I am able to execute

tasks such as hardware setup and cloud integration quickly. Furthermore, testing is given adequate time to guarantee that the system operates as intended prior to the final documentation process.

Streamlined Timeline: The project is planned to be completed in a logical order, beginning with research and hardware setup and progressing to programming and cloud integration. Testing and documentation will follow, ensuring that the system is fully operational and well-documented.

VIII. Ethical Considerations

Even though no personal data is being collected for this study, there are still ethical issues with cloud data security. In order to lessen the possibility of unwanted access:

Data Security: To ensure secure communication between the system and cloud, all data sent to the cloud will be encrypted using SSL/TLS protocols.

Privacy Compliance: The system will abide by privacy laws like the GDPR, guaranteeing that any information gathered and kept is handled securely and that only authorised users are able to access it.

IX. Conclusion

In conclusion, the problem of safe parking has an innovative solution in the form of the proposed Distance-Based Object Detection System for Parking Assistance. This system offers an affordable substitute for pricey commercial systems by integrating cloud-based data logging, real-time notifications, and inexpensive hardware. The system's capabilities will be improved and strengthened by future innovations, such as the integration of several sensors and GSM functionality, making it a reliable tool for preventing parking accidents.

References

[1] C. Lee, H. Kim, and Y. Yoon, "Vision-Based Parking Assist System," *2020 IEEE International Conference on Intelligent Vehicles (IV)*, Las Vegas, NV, USA, 2020, pp. 123-129. doi: 10.1109/IV47402.2020.9225406.

[2] H. Liu, A. Gomez, and A. Abbas, "Millimeter Wave Radar Technology for Autonomous Driving," *The Journal of Supercomputing*, vol. 75, no. 12, pp. 7859–7875, 2019. doi: 10.1007/s11227-019-02811-y.

[3] C. C. Chan and G. K. Dubey, "Ultrasonic Sensors for Object Detection," *Proceedings of the 2010 IEEE Conference on Intelligent Systems and Control*, Las Vegas, NV, USA, 2010, pp. 345-350. doi: 10.1109/ISCON.2010.5518412.