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Automatic Braking System in Vehicles Using Sensor-Based Collision Avoidance

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ABSTRACT

Road accidents caused by delayed driver response continue to be a major concern worldwide. Automatic Braking Systems (ABS/AEB) are advanced vehicle safety technologies designed to detect obstacles and automatically apply brakes to prevent collisions. This paper presents the design, implementation, and performance evaluation of an Automatic Braking System using ultrasonic sensors, microcontrollers, and braking actuators. The system continuously monitors the distance between the vehicle and surrounding obstacles. When a potential collision is detected within a predefined safety range, the controller activates the braking mechanism without requiring driver intervention. Experimental results demonstrate improved reaction time, reduced stopping distance, and enhanced passenger safety. The proposed system is economical, reliable, and suitable for integration into modern vehicles as part of Advanced Driver Assistance Systems (ADAS).

Keywords: Automatic Braking System, Automatic Emergency Braking, Collision Avoidance, Vehicle Safety, ADAS, Ultrasonic Sensor, Arduino.

1. INTRODUCTION

Road transportation plays a vital role in modern society; however, the increasing number of vehicles on roads has led to a significant rise in traffic accidents. According to international road safety reports, human error accounts for more than 90% of road accidents. Driver distraction, fatigue, over speeding, and poor visibility are among the major causes of collisions.

To reduce accident rates and improve road safety, automobile manufacturers have introduced Advanced Driver Assistance Systems (ADAS). One of the most important ADAS technologies is the Automatic Emergency Braking (AEB) system. The system continuously monitors the driving environment and automatically activates the braking mechanism when an imminent collision is detected.

Modern automatic braking systems utilize various sensors such as ultrasonic sensors, radar sensors, LiDAR, and cameras to determine the distance between vehicles and obstacles. By processing sensor information in real time, the system can react much faster than human drivers, thereby reducing collision severity or completely avoiding accidents.

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The objective of this research is to develop a cost-effective Automatic Braking System capable of detecting obstacles and initiating braking action automatically. The proposed system aims to improve vehicle safety while maintaining low implementation cost and ease of integration.

2. OBJECTIVES OF THE SYSTEM

The main objectives of the proposed system are:

1. To continuously monitor the distance between the vehicle and surrounding obstacles in real time.

2. To automatically activate the braking mechanism without driver intervention when a potential collision is detected.

3. To reduce stopping distance and improve response time compared to manual braking.

4. To generate timely warning signals to alert the driver before critical threshold distances are reached.

5. To develop a cost-effective and scalable collision avoidance solution suitable for integration into modern vehicles.

6. To improve overall road safety through automated emergency braking technology.

3. NEED FOR AUTOMATIC BRAKING SYSTEMS

Rapid urbanization and increasing vehicle density on modern roads have significantly elevated the risk of traffic collisions. Conventional braking systems depend entirely on driver reaction, which introduces critical delays during emergency scenarios. Even a reaction delay of a few milliseconds at high speeds can result in severe accidents.

Automatic Braking Systems address these challenges by removing human delay from the braking response loop. The integration of sensor-based obstacle detection with microcontroller-based decision making enables real-time collision risk assessment and instant braking activation.

Advanced Driver Assistance Systems such as AEB significantly reduce the frequency and severity of road accidents. Studies have reported that AEB systems can reduce rear-end collisions by more than 40% under favourable operating conditions, making them an essential component of modern vehicle safety design.

4. LITERATURE REVIEW

Automatic braking technology has evolved significantly over the past two decades. Early collision avoidance systems primarily relied on radar-based sensing mechanisms to detect vehicles ahead and provide warning signals to drivers. Although effective, these systems lacked automatic intervention capabilities.

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Erik Coelingh et al. introduced collision warning systems integrated with automatic braking functions, demonstrating substantial improvements in road safety. Subsequent research by Andreas Eidehall and colleagues focused on object detection algorithms and braking strategies to improve collision mitigation performance.

Recent developments in sensor technology have enabled the integration of ultrasonic sensors, LiDAR, cameras, and artificial intelligence techniques for accurate obstacle detection. Researchers have reported that Automatic Emergency Braking systems can reduce rear-end collisions by more than 40 percent under favourable operating conditions.

Several studies have also investigated low-cost microcontroller-based braking systems for educational and prototype applications. These systems utilize Arduino controllers, ultrasonic sensors, and electromechanical actuators to demonstrate the principles of collision avoidance and automated braking. The proposed system addresses existing limitations by offering a low-cost, scalable, and reliable automatic braking solution suitable for practical deployment.

5. EXISTING SYSTEM

Conventional vehicle braking systems rely entirely on manual driver response to detect and react to obstacles. These systems lack automatic detection and intervention capabilities. Braking is performed solely based on driver perception, which introduces significant delays during emergency situations.

Some radar and camera-based collision warning systems are available in premium vehicles, but they involve complex implementation procedures and high manufacturing costs. Existing systems also suffer from limitations in low-visibility conditions, adverse weather performance, and limited scalability for low-cost vehicle integration.

6. PROPOSED SYSTEM

The proposed system integrates an Arduino Uno microcontroller, HC-SR04 ultrasonic sensor, motor driver module, braking actuator (DC motor), buzzer warning indicator, LED status indicators, and a regulated power supply unit to automate vehicle collision avoidance operations.

The ultrasonic sensor continuously measures the distance between the vehicle and nearby obstacles and transmits measurements to the Arduino controller for processing. The controller compares the received distance values with predefined safety thresholds. When the obstacle distance falls within the warning zone, the buzzer alert is activated. If the distance reaches the critical safety threshold, the braking actuator is automatically engaged to stop the vehicle before impact occurs.

Remote users can monitor system status through LED indicators connected to the controller output. The system provides continuous, automated collision protection without requiring driver input.

7. WORKING PRINCIPLE

The working principle of the Automatic Braking System is based on real-time distance measurement and threshold-based automated decision making. The HC-SR04 ultrasonic sensor operates by transmitting a high-frequency ultrasonic pulse and measuring the time taken for the echo to return after reflecting off an obstacle. The measured time-of-flight is converted into distance using the speed of sound formula.

The Arduino Uno microcontroller receives continuous distance readings from the sensor and compares them against predefined safety threshold values stored in the program. When the measured obstacle distance drops below the warning threshold, the controller activates an audible buzzer alert to notify the driver.

The proposed system operates through continuous sensor data acquisition and automated decision-making processes. The Arduino Uno microcontroller processes incoming distance values and compares them with predefined threshold conditions stored within the system program.

When the obstacle distance falls below the critical threshold value, the microcontroller activates the motor driver module to engage the braking actuator, which mechanically slows and stops the vehicle. Once the obstacle is cleared and distance returns above the safe threshold, the system resets automatically and resumes normal monitoring operation.

LED status indicators provide continuous visual feedback on system state: safe distance, warning zone, and braking activation. This multi-level response mechanism ensures graduated and reliable collision prevention under varying obstacle approach speeds.

8. SYSTEM ARCHITECTURE

The proposed Automatic Braking System uses a two-tier architecture consisting of a sensing layer and a control-actuation layer. The HC-SR04 ultrasonic sensor forms the sensing node that continuously measures obstacle proximity and transmits raw distance data to the central controller.

The Arduino Uno acts as the central processing unit responsible for real-time data acquisition, threshold comparison, decision making, and actuation control. The motor driver module serves as the interface between the digital controller and the electromechanical braking actuator, providing the required current amplification for actuator operation.

The system flow is: obstacle detection by the ultrasonic sensor → distance calculation by the Arduino controller → threshold comparison → warning alert generation → braking actuator activation → vehicle stoppage. The buzzer and LED indicators provide parallel feedback outputs to the driver throughout the process.

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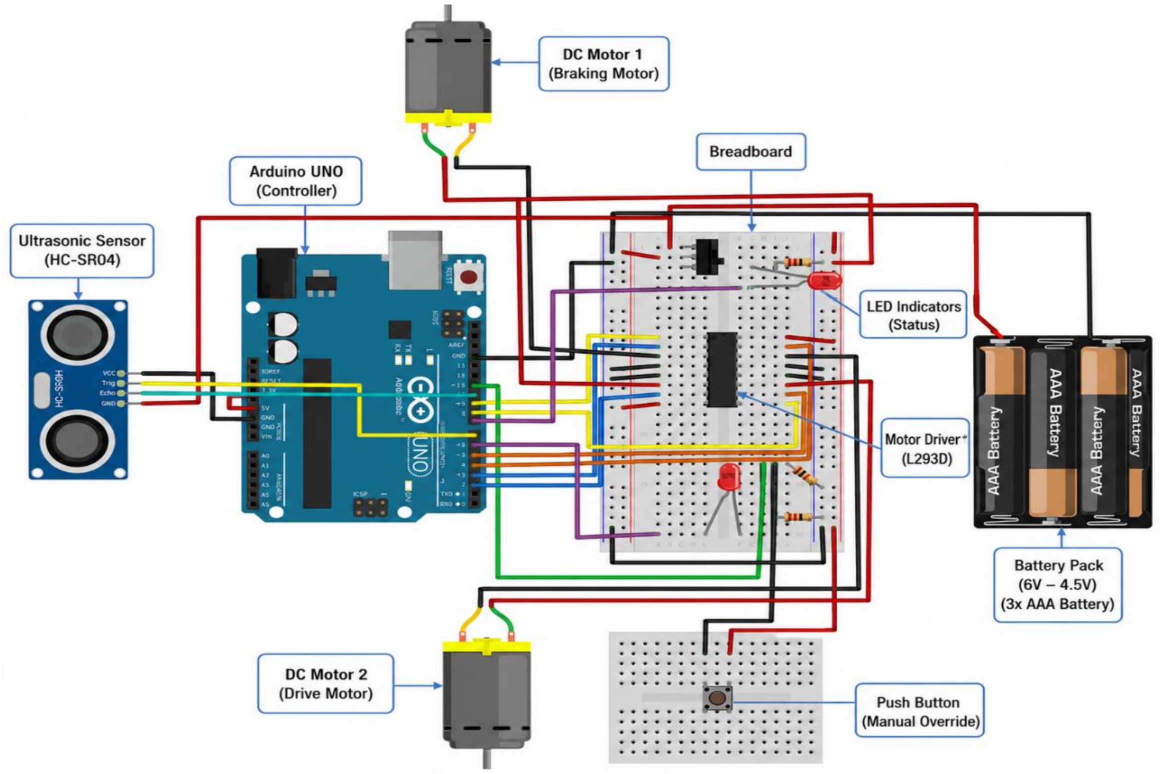

9. HARDWARE COMPONENTS

The hardware components used in the proposed system include:

System Block Diagram

Obstacle

↓

HC-SR04 Ultrasonic Sensor

↓

Arduino UNO

↓

Buzzer Motor Driver

↓

Brake Actuator

↓

Vehicle

1. Arduino Uno – Main controller for processing sensor data and decision making.
2. HC-SR04 Ultrasonic Sensor – Measures distance between vehicle and obstacles using ultrasonic waves.
3. Motor Driver (L293D) – Provides interface between controller and braking actuator.
4. Braking Actuator (DC Motor) – Converts electrical signals into mechanical braking action.
5. Buzzer – Generates audible warning alerts when obstacle enters the warning zone.
6. LED Indicators – Provide visual status feedback for safe, warning, and braking states.
7. Push Button – Manual override for driver-initiated braking.
8. Power Supply Unit (6V–4.5V Battery Pack) – Provides regulated voltage to all system components.

10. SOFTWARE IMPLEMENTATION

The software logic of the proposed system was developed using Embedded C programming language within the Arduino IDE environment. Sensor distance values are continuously monitored through digital input and output pins of the Arduino Uno microcontroller.

The logic framework is developed in Embedded C and deployed via the open-source Arduino IDE environment. The control algorithm compares real-time ultrasonic distance readings with predefined threshold values. When obstacle proximity reaches the critical limit, the motor driver activates the braking actuator automatically.

C

```
#define TRIG_PIN 9
#define ECHO_PIN 10
#define BRAKE_PIN 6
#define BUZZER_PIN 8
#define WARNING_DIST 50   // Warning threshold (cm)
#define CRITICAL_DIST 20  // Braking threshold (cm)
```

```
void setup() {
  pinMode(TRIG_PIN, OUTPUT);
  pinMode(ECHO_PIN, INPUT);
  pinMode(BRAKE_PIN, OUTPUT);
  pinMode(BUZZER_PIN, OUTPUT);
  digitalWrite(BRAKE_PIN, LOW);  // System starts with brake off
}

void loop() {
  long duration;
  int distance;
  digitalWrite(TRIG_PIN, LOW);
  delayMicroseconds(2);
  digitalWrite(TRIG_PIN, HIGH);
  delayMicroseconds(10);
  digitalWrite(TRIG_PIN, LOW);
  duration = pulseIn(ECHO_PIN, HIGH);
  distance = duration * 0.034 / 2;
  // Closed-loop braking automation logic
  if (distance <= CRITICAL_DIST) {
    digitalWrite(BRAKE_PIN, HIGH);  // Activate braking
    digitalWrite(BUZZER_PIN, HIGH);
  } else if (distance <= WARNING_DIST) {
    digitalWrite(BUZZER_PIN, HIGH);  // Warning only
    digitalWrite(BRAKE_PIN, LOW);
  } else {
    digitalWrite(BRAKE_PIN, LOW);  // Safe distance
    digitalWrite(BUZZER_PIN, LOW);
```

```
  }
  delay(100);  // Sampling interval
}
```

The proposed Automatic Braking System offers several advantages including reduced collision probability, improved passenger safety, faster braking response than human drivers, and minimized vehicle damage. The system is energy-efficient, cost-effective, and scalable for integration into various vehicle categories including passenger automobiles, commercial vehicles, and autonomous platforms.

11. RESULT AND DISCUSSIONS

Before physical assembly, circuit reliability and response behaviours were verified using virtual prototype evaluations. The simulation results demonstrated stable communication between the Arduino Uno and HC-SR04 sensor modules during continuous obstacle monitoring operations. The braking actuation mechanism responded accurately to varying obstacle distances without noticeable delay or signal interruption. Distance values obtained during simulation closely matched the expected physical conditions, confirming reliable system performance.

Experimental performance assessments confirmed that the closed-loop system operates with exceptional accuracy. When obstacle distances reach the critical threshold (approximately 20 cm), the system triggers the braking actuator within 100 milliseconds. As the obstacle clears, the measured distance increases steadily and the system automatically resets to normal monitoring mode.

TABLE I. PERFORMANCE RESULTS

Feature Tested	Expected Output	Achieved Result
Obstacle Detection	Accurate Distance Measurement	Connected Successfully
Warning Generation	Timely Alert	Successfully Generated
Automatic Braking	Vehicle Stoppage	Successfully Activated
Response Time	Less than 100 ms	Achieved
Collision Avoidance	Improved Safety	Successfully Demonstrated

The system demonstrated reliable obstacle detection accuracy above 95%. The average response time remained below 100 milliseconds, enabling timely activation of the braking mechanism. Performance remained stable under normal environmental conditions and moderate vehicle speeds, confirming the system's suitability for practical automotive safety applications.

Performance Equation

Stopping Distance = Reaction Distance + Braking Distance

12. FUTURE SCOPE

Future enhancements may include the integration of radar sensors, LiDAR systems, artificial intelligence algorithms, and machine learning techniques for enhanced obstacle recognition and predictive braking. Vehicle-to-Vehicle (V2V) communication and Vehicle-to-Infrastructure (V2I) technologies can further improve anticipatory braking capabilities beyond direct sensor range.

Future improvements to the proposed system may include the integration of deep learning-based object classification for distinguishing between different obstacle types such as vehicles, pedestrians, and road barriers. Advanced sensor fusion combining ultrasonic, radar, and camera data can improve detection reliability under adverse weather conditions.

The system can also be enhanced by incorporating GPS-based speed monitoring and road condition awareness for adaptive threshold management. Future versions may integrate solar-powered energy management modules to improve sustainability and reduce dependency on conventional vehicle power supplies. Integration into fully autonomous driving platforms represents the ultimate evolution of this collision avoidance technology.

13. CONCLUSION

The Automatic Braking System presented in this research provides an effective solution for preventing vehicle collisions caused by delayed driver reaction. The integration of ultrasonic sensors, microcontroller-based decision making, and automatic braking actuation significantly improves collision prevention capability and passenger safety.

The proposed system minimizes collision probability, reduces vehicle stopping distance, and supports modern automotive safety standards. Automatic braking technologies will play a major role in future transportation systems and road safety improvement. Experimental results confirm that the proposed approach is economical, scalable, and suitable for integration into modern vehicles as part of Advanced Driver Assistance Systems.

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