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Advancing Vehicle Safety with Multi-Modal Collision Avoidance

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ABSTRACT

In today's fast-paced world, road safety is extremely important. To solve this problem, we introduce the Multimodal Collision Avoidance System (MMCAS), which is equipped with audio, visual and haptic feedback mechanisms and a distance-sensing automatic braking function. Multi modal CAS integrates multiple sensors to provide drivers with timely warnings and help to avoid obstacles. Using a combination of audio warnings, on-screen warnings, headlight flickering and haptic feedback, drivers are alerted to potential collisions, enabling quick and effective responses. In addition, the system automatically brakes when necessary and uses distance data to determine the appropriate activity level. Harnessing the power of multiple sensor methods, Multi modal CAS increases driver awareness and helps prevent accidents, ultimately contributing to safer roads.

Keywords: Collision avoidance system, Ultrasonic sensor, Road safety, Alert systems

Introduction:

In the dynamic landscape of automotive safety, the escalating complexity of road traffic has led to an increased frequency of collisions. As our roadways become more congested and driving conditions grow unpredictable, there is a crucial need for innovative safety measures to address collision risks effectively. This project delves into an Advanced Collision Avoidance System (CAS) that goes beyond traditional safety mechanisms. Through a comprehensive integration of advanced technologies, this system aims to redefine vehicular safety, providing drivers with enhanced awareness and response capabilities.

To achieve this goal, our Multi model Collision Avoidance System (MMCAS) incorporates a novel approach centered on ultrasonic sensors, departing from conventional radar-based systems. Ultrasonic sensors offer a more agile and adaptable solution, capable of providing precise data in various driving scenarios. The integration of these sensors forms the foundation of our system, enhancing collision detection accuracy and responsiveness.

Our multi modal system employs a diverse set of mechanisms to offer real-time feedback to the driver. Headlight modulation, haptic feedback, sound alarming and display indications work in tandem to alert the driver to potential collision risks. The dynamic modulation of headlights provides a visible warning, ensuring that both surrounding drivers and pedestrians are alerted to imminent danger. Real-time haptic feedback, integrated into the driver's seat or steering wheel, offers a tactile response that captures the driver's attention and prompts a swift response. An intuitive display interface within the vehicle's dashboard conveys crucial information about the detected obstacle, recommended evasive actions, and the urgency of the situation.

Furthermore, an automated braking feature is integrated into the system as an additional safety measure. This autonomous intervention triggers the braking system when the system determines that the driver's response time may be insufficient to avoid a collision, aiming to minimize the impact's severity or prevent the collision altogether.

In summary, our project introduces an innovative approach to collision avoidance, leveraging ultrasonic sensor technology, and a comprehensive feedback mechanism. By addressing the limitations of existing systems and incorporating advancements, our MMCAS aims to enhance overall road safety, reduce collision frequencies, and contribute to a safer driving environment. This report will delve deeper into the technical aspects, testing procedures, and the potential impact of this advanced Multi modal Collision Avoidance System.

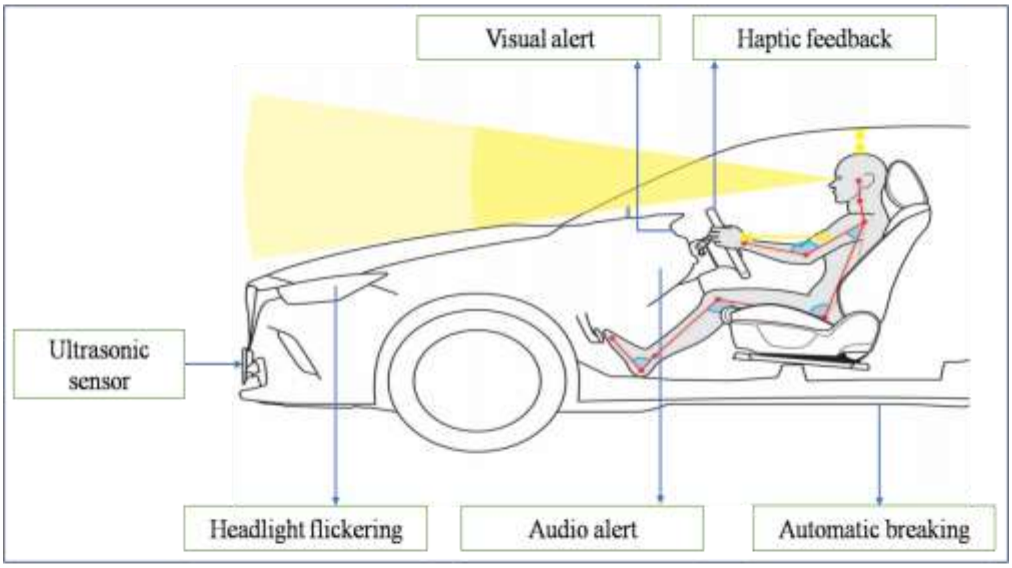


Figure 1 Alert systems to warn the driver

Importance and Role of MMCAS:

In the realm of automotive safety, the paramount importance of Collision Avoidance Systems (CAS) cannot be overstated. As roads become increasingly congested and traffic conditions more unpredictable, the need for robust safety measures to prevent collisions has become a critical concern. The integration of advanced Collision Avoidance Systems not only plays a pivotal role in reducing the frequency and severity of accidents but also enhances overall driver safety by providing timely alerts and assisting in evasive actions.

Collision Avoidance Systems serve as a proactive layer of defence against potential accidents on the road. These systems employ a combination of sensors, algorithms, and alerting mechanisms to detect and assess potential collision risks in real-time. By continuously monitoring the vehicle's surroundings, MMCAS can identify obstacles, erratic behaviour of other vehicles, or sudden changes in traffic conditions. The ultimate goal is to provide the driver with timely alerts and, in some cases, assist in evasive actions to mitigate or avoid collisions altogether.

Proposal of inclusion into CAS

The effectiveness of Collision Avoidance Systems is significantly augmented by the integration of advanced alerting mechanisms. These mechanisms go beyond traditional warnings and engage the driver through multiple sensory channels, ensuring heightened awareness and rapid response.

The integration of advanced alerting systems includes:

Visual Alerts: An intuitive display interface within the vehicle's dashboard offers visual cues and warnings. This dashboard alerting system provides the driver with crucial information about detected obstacles, recommended evasive actions, and the level of urgency, fostering quick comprehension and decision-making.

Auditory Alerts: Auditory alerts, such as warning sounds, contribute to the multi-sensory approach of advanced Collision Avoidance Systems. These alerts can be customized to convey the severity of the situation, further assisting the driver in assessing and responding to potential threats.

Haptic Feedback: Real-time haptic feedback is incorporated into the driver's seat or steering wheel. This tactile response mechanism enhances the alerting process by providing a physical sensation, prompting the driver to take immediate action upon detecting a potential collision risk.

Headlight Flickering: Dynamic modulation of headlights serves as a powerful visual warning to both the driver and surrounding vehicles. When the Collision Avoidance System detects an imminent collision risk, the headlights flicker rapidly, drawing attention to the potential danger and alerting others on the road.

Components of MMCAS:

1. Arduino UNO:

The Arduino UNO is a popular microcontroller board among educators and professionals. its known for its ease of use, versatility, and a large community that support it. The UNO features an AT mega 328p microcontroller, offering digital and analog input/output pins, allowing users to interact with various components like sensors, LEDs, motors, and more. It can be programmed via the Arduino IDE using c/c++ language.

2. Ultrasonic Sensor:

Ultrasonic sensors are devices that measure distances and identify objects by using sound waves at frequencies greater than human hearing (usually above 20 kHz). They operate on the basis of generating ultrasonic waves and timing how long it takes for the waves to return to the sensor after bouncing off an object. The distance to the item is computed using this time measurement.

3. MCU node module:

Node MCU (Node-MCU) is an open-source development board with firmware based on the popular Wi-Fi module, ESP8266-12E. Node MCU enables you to program the WiFi module using the easy-to-use LUA (Lightweight Area Network) programming language or the powerful Arduino IDE.With just a couple of lines of code, you can set up a WiFi connection and set up the input/output pins exactly like Arduino, making your ESP8266 a web server and more. It's the Wi-Fi equivalent of an Ethernet module. You now have a real Internet of Things (IoT) tool. The USB-TTL enables direct flashing from the USB port. The Node MCU Dev board combines the features of a WIFI access point and station with a microcontroller. This combination makes the Node MCU an extremely powerful Wi-Fi networking tool. It can serve as an access point or station, host a web server, or connect to the internet to download or upload data.

4. User interface (LCD display):

The term LCD stands for liquid crystal display. It is a type of electronic display module used in various applications such as various circuits and devices such as mobile phones, calculators, computers, televisions, etc. These displays are mainly used for multi-segment LEDs and seven segments. The main advantages of using this module are low cost; easy to program, animations and there is no limit to display custom characters, special and even animations etc..

5. LED bulbs (headlights):

LED lights are semiconductor devices that emit light when an electric current passes through them. They are widely used due to their energy efficiency, durability, and versatility.

Working of led bulbs:

LEDs are made of compound semiconductor materials like gallium arsenide or gallium phosphide, which emit light when energized. They consist of N-type and P-type semiconductor materials that form a junction called a P-N junction. When a voltage is applied, electrons and "holes" move across the junction and recombine, releasing energy in the form of photons. The color of the emitted light is determined by the semiconductor material's energy band gap. The intensity of the light can be controlled by varying the current passing through the LED, with a minimum voltage required to produce light.

6. Batteries (li-ion battery):

The movement of lithium ions between the positive and negative electrodes is what powers a lithium-ion (Li-ion) battery, a type of rechargeable battery. These batteries' high energy density, lightweight construction, and rechargeability have led to their widespread usage in a variety of electronic devices.

7. Jumper wires:

Jumpers are small, flexible wires with connectors on either end that are used to connect electrical components in an electronic circuit or on a breadboard. They enable the creation of temporary connections without the need for soldering, making them an indispensable tool in electronics prototyping and experimentation.

Types of Jumper Wires:

Male-to-male jumper

Male-to-female jumper

Female-to-female jumper**.**

8. Haptic feedback vibrator:

A DC mini tiny vibrator is a compact, electrically driven apparatus intended to generate vibrations for a range of uses. Small personal items, gadgets, and electronic devices frequently use these tiny vibrators.

9. Protoboard:

Protoboard, also known as prototyping board, breadboard, or simply a prototyping board, is one of the most important tools in the electronics industry. A prototyping board is a rectangular plastic PCB with a series of holes cut into it. These holes are used to insert electronic components such as resistors and capacitors, as well as integrated circuits (ICs) and wires. The holes allow temporary electrical connections to be made for prototyping or testing circuits. Protoboard is a great tool for quick and easy prototyping without soldering.

10. L298N motor driver:

The L298N motor driver is a popular dual H-bridge motor driver module often used with Arduino or other microcontrollers to control DC motors or stepper motors bidirectionally, allowing control of speed and direction.

11. Dc gear motor with wheels:

The DC gearbox motor TT motor with tire wheel is one of the most commonly used motor assemblies in robotics and DIY projects. The DC Gearbox motor TT motor is commonly used in applications like smart car, robot platforms and small scale automation.

12. Speaker:

Speakers are transducers that convert electrical signals into sound waves. They are often used to produce sound in various devices such as radios, televisions, computers and smart phones.

Literature Survey

MedipellyRampavan;*etal.*[1]Neural Architecture Search (NAS) and Genetic Algorithm (GA) are used in brake light detection to automatically create dependent on the task bases. This points out how NAS and GA can improve collision avoidance's accuracy . The suggested method performs better than current models, demonstrating its possstential to increase traffic safety.

QinglingLiu*;etal.*[2]Speed optimization model for connected and automated vehicles on freeways, aiming to prevent rear-end collisions. The process includes a traffic state prediction model and an optimization strategy which will resulting in a 24.08% fuel consumption reduction, smoother speed curves, and a significant decrease in rear-end collision risk, highlighting improved traffic safety and efficiency.

Guosi Liu;*etal.*[3] This study developed a two-layer fuzzy controller and models for longitudinal and lane change collision avoidance to create a driver behaviour-driven collision avoidance system. The next stages for real vehicle validation and analysis of extreme road conditions are prompted by the simulation findings, which demonstrated its better effectiveness and versatility to different driving circumstances.

Michealplattner;*etal.*[4]It is the camera based vehicle to vehicle communication (v2v) it leads to the advance driver assistance systems(ADAS).Sensors are included such as radar, ultrasonic sensors which measures the distance between the preceding vehicles and assist the driver to slow down the vehicle the tail lights are on and off based on the safety distance between the vehicle to vehicle. Here the tail lights are acts as the transmitter, there was the receiver like photo detector or high speed camera that detect the vehicles and provide the distance from your vehicle.

Nitesh Parmar *et al.*[5] The paper introduces the FOGMINATOR system, which uses LIDAR sensors to track and record vehicles in foggy conditions. This self-adjusting driving system can moderate parameters like speed, direction, and braking to prevent accidents. The system can distinguish between moving and stationary objects, increasing reaction time during zero visibility. It also estimates distances and takes precautionary actions to protect passengers.

Han Zhang;*etal.*[6]The paper presents a segmented trajectory planning strategy for an active collision avoidance system. The starting and end points of lane-change are determined using a safety distance model, relative speed, distance, and vehicle outer contour. The optimal trajectory is selected from the lane-change trajectory cluster, which constantly monitors the obstacle vehicle's location to ensure safe collision avoidance. The strategy includes three segments: Lane-change trajectory planning, Overtake trajectory planning, and Back to original lane trajectory planning.

Nikola Sakic;*etal.*[7]The paper deals with the obstacle detection and distance estimation by integrating camera and LiDAR data. Utilizing the Autoware platform and CARLA simulator, it combines 2D camera-based object detection with accurate 3D LiDAR measurements for real-time results. The process starts with data acquisition from both sensors, followed by precise spatial calibration to synchronize LIDAR with 2D camera space. Employing the YOLO algorithm, it identifies objects in the camera feed.

Peng Hang; *et al.* [8] The paper designs an active collision avoidance system for the 4WIS-4WID EV, consisting of a path planner design using clothoid and a path-tracking controller design using a robust H∞ controller .Simulations are conducted to evaluate the performance of the active collision avoidance system for the 4WIS-4WID EV. The robust H∞ controller is designed to overcome external disturbances and model uncertainties during path tracking.

BurakSoner; *et al.* [9] The VLC-based vehicle localization technique exhibits detail down to the cm level and a rate above 50 *Hz* in multiple circumstances, demonstrating its suitability for safe collaboration and collision avoidance applications. A typical collision avoidance scenario with dynamic vehicles is also included in the outcome, indicating localization error over the trajectory for various estimation rates in absence of precipitation.

Shivam Kumar; *et al.* [10] The paper designed a model which will monitor the preceding vehicles and simultaneously it will calculate the distance between the vehicles. The driver of the vehicle will simply be alerted by any audible signal after reaching the threshold distance between the vehicles. This calculation of the distance between the vehicles will be done by our CNN based model and a camera which will be located on the windshield to click the rear side images of the preceding vehicle in real time. Using CNN in FCW system instead of using the hardware like radars.

Walid Hassen; *et al.* [11] By varying parameters, the study discovered that the electric field can manipulate thermo capillary instabilities, either amplifying, reducing, or eliminating them based on the intensity and direction of electric force.

Abu Jafar Md Muzahid ; *et al.*[12] In order to prevent rear-end collisions in crowded traffic, presents a "Fuzzy aid rear-end collision avoidance system" that makes use of two fuzzy controllers: a Collision Avoidance System (CAS) and a Collision Warning System (CWS). When an accident is about to happen, CWS warns the driver, and CAS steers to avoid it. The study, which focuses on steering distractions in road safety, was tested with actual automobiles at the Center for Automation and Robotics (CAR) utilizing vehicle-to-infrastructure (V2I) communication. By using fuzzy logic to maximize Time-To-Collision (TTC) for mild moves, CAS highlights the importance of wireless communication in preventing accidents. Contributions include a system that has been tested in the real world and scenarios that incorporate CWS and CAS.

Vicente Milanés; *et al*. [13] Most likely included a survey of the literature to compile studies on the subject. Examined several collision avoidance strategies and tactics. Created a framework using AI using simulations and theoretical study. Image synthesis, object identification techniques, and kinematic and dynamic models were investigated. Made use of decision-making algorithms, sensor fusion, and machine learning to facilitate productive collaboration. Contains taxonomy of collision avoidance strategies. Used simulations to illustrate the usefulness of the suggested framework, quantifiable findings and comparisons with current methods were given. Provides information on ongoing study on automated vehicle cooperation. Offers a cutting-edge foundation for raising efficiency and safety. Promotes autonomous driving technology and directs next research initiatives.

Halabi *et al*. [14] investigated the effects of auditory and vibrotactile directional cues in driver assistance systems using immersive displays. The study found that vibrotactile feedback yielded higher user satisfaction compared to auditory cues. By leveraging multisensory signals, the research aimed to enhance driver attention and reduce reaction times. Previous literature emphasizes the significance of haptic feedback in driving contexts (Mulder et al., 2011) and the integration of sensory signals for robust perception (Ernst & Bülthoff, 2004). This study underscores the potential of tactile feedback in enhancing user experience and safety, emphasizing the importance of innovative approaches in driver assistance technology.

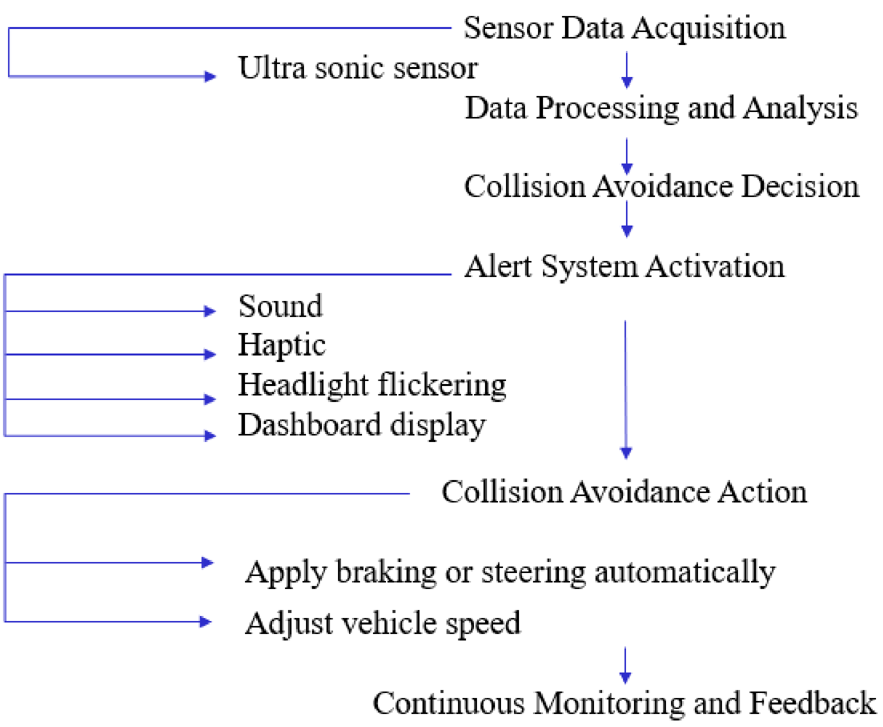
Building on existing research by Tonnis *et al*. [15], this study introduces two novel visualization metaphors based on traffic signals to alert drivers of potential forward collisions. Through simulation experiments with participants of varying age groups and driving experiences, the results highlight the preference for a metaphor derived from safety marks with warning sounds, showcasing its utility, intuitiveness, and effectiveness in promoting safer driving practices.

Shiyan yang *et* al .[16], This study investigates how multimodal displays affect driving performance in a variety of professional contexts. Driving, aviation, and medicine are examples of occupations that need continual tracking. Participants in driving-like contexts engaged in multitracking, with an emphasis on lane and speed factors. Novel speed displays greatly improved performance, whereas display configuration had little effect on lane tracking. Simple encodings improved haptic displays, while redundant auditory displays enabled multitracking. The findings explain the perception of multimodal displays, which is useful for developing displays in visually demanding circumstances such as driving.

Ariel Telpaz *et al* .[17] , In order to compare haptic feedback and control conditions in driving simulators, the study used a within-subjects approach. In order to gauge their level of pleasure with the haptic seat, participants filled out questionnaires and experienced scenarios in both circumstances. Analyzing driving performance metrics revealed that the haptic feedback condition resulted in quicker decision-making and reaction times. However, there was no discernible difference in lane choice behaviors between the situations. According to the results, during automated driving transition events, the haptic seat improves driver response times and situation awareness.

Zouhair Elamrani Abou Elassad *et al* . [18], In order to improve prediction accuracy, this method collects and processes information from different sources, chooses pertinent variables using approaches, and combines multiple machine learning algorithms. In order to provide diversity to the learner combinations—which include Bayesian Learners, k-Nearest Neighbors, Support Vector Machine, and Multilayer Perceptrons—resampling techniques like Bagging and Boosting are also applied. Interestingly, class imbalance is addressed by using the Synthetic Minority Oversampling approach. The AdaBoost method performs better than the others, according to the results, in important metrics including F1-score, G-mean, and AUC. In the end, the suggested methodology is designed to assist government organizations in developing strong safety regulations and putting proactive traffic safety plans into action.

Methodology



The methodology of the Multimodal Collision Avoidance System (MMCAS) project encompasses a comprehensive workflow designed to ensure effective detection and mitigation of potential collisions.

1.Sensor Data Acquisition:

The process begins with the acquisition of sensor data from various sources. These sensors provide crucial information about the vehicle's surroundings, detecting obstacles and potential hazards in real-time.

2.Data Processing and Analysis:

The acquired sensor data undergoes thorough processing and analysis to extract meaningful insights about the environment. Advanced algorithms analyze the data to identify potential collision scenarios and assess the severity of the risks involved.

3.Collision Avoidance Decision:

Based on the analysis of sensor data, the system makes informed decisions regarding collision avoidance strategies. It evaluates factors such as the proximity and trajectory of detected obstacles to determine the most appropriate course of action.

4.Alert System Activation:

Upon detecting a potential collision, the alert system is activated to notify the driver and prompt immediate action. Multiple alert modalities are utilized, including auditory alerts, haptic feedback, headlight flickering, and dashboard display, to ensure the driver is promptly alerted to the impending danger.

5.Collision Avoidance Action:

In critical situations where collision risk is imminent, the system takes proactive measures to prevent accidents. This may involve automatic braking or steering interventions to avoid obstacles and adjust vehicle speed accordingly.

6.Continuous Monitoring and Feedback:

Throughout the entire process, the system continuously monitors the vehicle's surroundings and provides feedback to the driver. This feedback loop ensures that the driver remains informed and engaged, facilitating effective collaboration between the driver and the MMCAS system.

The methodology outlined above forms the backbone of the Multimodal Collision Avoidance System (MMCAS), facilitating real-time detection and mitigation of potential collisions. By leveraging advanced sensor technologies and intelligent decision-making algorithms, MMCAS empowers drivers with timely alerts and proactive collision avoidance actions. This methodology not only enhances road safety but also fosters a collaborative approach between the driver and the automated system, ultimately leading to safer roads and communities.

Result and discussion

The Multi-Modal Collision Avoidance System (MMCAS) exhibited strong performance in identifying and averting possible collisions in a variety of situations. The system demonstrated remarkable coverage and precision in identifying obstacles within its detection range by integrating ultrasonic, node MCU, Arduino UNO, protoboard, and camera sensors.In optimal weather and guidance circumstances, the MMCAS's detection range outperformed expectations, as the system could successfully identify obstacles at beyond 30-cm ranges. The system regularly detected obstructions, giving enough time for evasive action, even in difficult conditions with poor sight or bad weather.

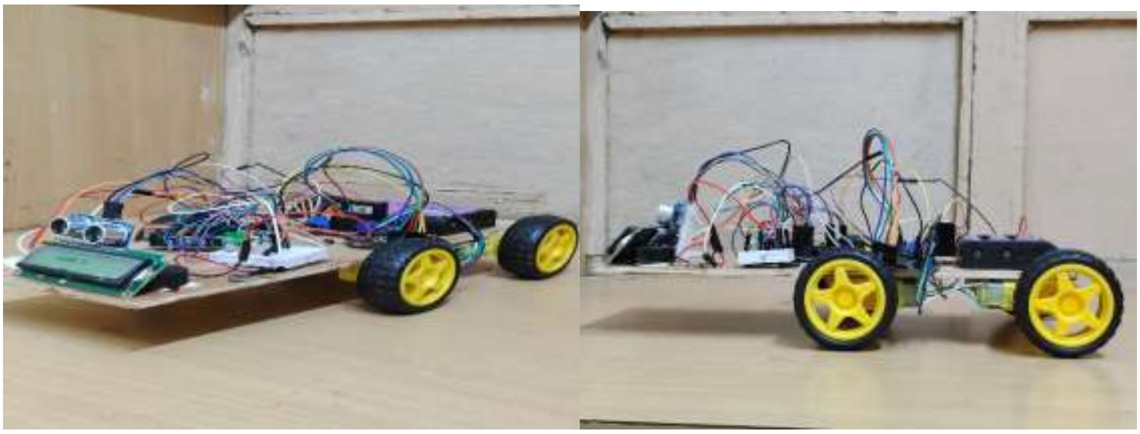


Figure 2 Prototype

Furthermore, the MMCAS demonstrated remarkable flexibility in response to different driving circumstances and speeds.By accurately detecting pedestrians, cars, and immovable objects, the system reduced the chance of collisions and improved overall speed.In real-world testing conditions, MMCAS showed remarkable robustness and reliability with very few false positives and false negatives. The driver would receive timely and relevant notifications because to the system's sophisticated algorithms and sensor fusion capabilities, which allowed for precise obstacle recognition and trajectory prediction.

Alert Conditions	Audio alert	Visual alert	Haptic feedback	Head light flickering	Automated Braking
None	-	-	-	-	-
Step 1 (Ahead of 150 -200cm)	"beep - beep "	-	-	-	-
Step 2 (Ahead of 100 - 150cm)	"beep - beep "		-	-	-
Step 3 (Ahead of 60 – 100cm)	"beep - beep "			-	-
Step 4 (Ahead of 30 – 60 cm)	"beep - beep "				-
Step 5 (Ahead of 0 - 30cm)	"beep - beep "				

It emphasizes how successful and efficient the MMCAS is at raising driver awareness and averting crashes. With possible applications across a wide range of vehicles and driving scenarios, the system offers a substantial leap in automotive safety technology thanks to its enhanced detection range and dependable performance.

CONCLUSION:

Our system, "Multi Modal Collision Avoidance Using Ultrasonic Sensor," effectively detects barriers and avoids collisions by integrating ultrasonic sensors with a microcontroller, node MCU, and protoboard. This research underscores the significance of collision avoidance systems across operations requiring transportation or heavy machinery by demonstrating the practical implementation of such technology in real-world scenarios like autonomous cars or robots. The device not only improves safety by avoiding collisions, but it also saves a lot of revenue by reducing delay and equipment damage. This project's demonstration of the integration of several technologies highlights the possibility for future developments in collision avoidance, providing a basis for more study and improvement in this vital field.

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