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A Hybrid Control Approach for Autonomous Robotic Cars: Combining Voice, Bluetooth, and Obstacle Detection

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Abstract: This paper describes a new type of control for self-driving robotic cars that combines three modes of interaction: voice control, Bluetooth communication, and real-time obstacle detection. The primary goal of this system is to improve the operational flexibility and effectiveness of self-improving vehicles, thus increasing their usability with different settings and user requirements. In this case, the user can operate the control functions like navigation and speed adjustment hands-free and give commands through voice control. Communication via Bluetooth enables connection with mobile devices where the user can log in, monitor, or even change information. Furthermore, Automatic Obstacle Detection using ultrasonic sensors improves the real-time hazard avoidance capabilities of the robotic cars which improves safety and reliability. Using these three control methods, the electric car is able to function either autonomously or with human input, while at the same time being able to respond to environmental changes and optimize performance and user satisfaction. These results suggest that hybrid control systems used in autonomous robotic car have developed further in their application scope and complexity for real world challenges.
Keywords: Obstacle avoidance, Bluetooth communication, voice recognition, ultrasonic sensor, wireless control

I. INTRODUCTION

The emergence of self-systems has changed the landscape of modern technology with machines capable of performing activities that, until then, required immediate human involvement. Ranging from smart assistants and production line automation to intelligent transport, the requirement for autonomous vehicles (AVs) is emerging at an exponential rate with the potential to increase safety, productivity, and user experience. particularly in the field of mobility and robotics, autonomous robotic cars present a vision of flexible movement, human-robotic interaction, and automatic conveyance within household and industrial environments. Traditional robot automobiles have predominantly employed single-mode control systems—remotely operated by means of Bluetooth, IR remotes, or programmed to travel along predetermined routes with the aid of sensors. These systems are typically insufficient within dynamic environments with changing user preferences, real-time decision-making requirements, and safety issues. To overcome these deficiencies, hybrid control systems emerged as a versatile solution with the ability to be combined from multiple input modalities so that robots could make smart choices and interact with people in a more natural way.

The following article presents a novel hybrid model of control for autonomous robotic vehicles through the integration of voice recognition, Bluetooth communication, and real-time
ultrasonic avoidance sensing. All of these methods possess their own specific strengths:

Voice Recognition: Offers a natural and hands-free method of control. It renders the system more comfortable, especially for physically handicapped users or where manual control is not feasible. Natural language comprehension and onboard voice recognition modules have improved, making this method more practical for use.

Bluetooth Communication: Acts as an interface between the robot and external mobile devices, through which users can interact utilizing mobile apps or terminal commands. Bluetooth provides a reliable short-range communication protocol that does not depend on internet access, making it extremely user-friendly in indoor environments.

Obstacle Detection: A critical aspect of autonomous decision-making, obstacle detection allows the vehicle to perceive the environment and avoid collisions. Through the assistance of ultrasonic sensors, the robot can sense distances to objects nearby and adjust its movements accordingly, enabling safe travel even in dense or unfamiliar surroundings.

All these control systems allow the robotic vehicle to move autonomously and semi-autonomously, with the ability to switch modes depending on user input or environmental conditions.

For instance, a user can issue a voice command to initiate movement, followed by Bluetooth control for precise movement, with the obstacle detection system continuously available for safety. What sets this work apart is its focus on integrally combining these technologies onto one embedded platform. While many studies have focused on the individual subsystems—such as voice-activated robots or Bluetooth-enabled RC cars—few have even proposed and created an actual hybrid framework that combines all three methods into a single structure. The primary challenge lies in coordinating these inputs and enabling the robot to put safety ahead of conflicting commands, which this paper addresses through intelligent logic design and coordination of systems.

Technically, the project uses inexpensive and readily available components such as the Arduino Uno microcontroller, HC-05 Bluetooth module, HC-SR04 ultrasonic sensor, and basic voice recognition module, hence it is reproducible and a good project for academic, prototyping, or training purposes. The robot's mobility is facilitated by two DC motors driven by an L298N motor driver, offering stable speed and direction control. The aim of this study is not only to validate the feasibility of the hybrid system but also to experiment with its accuracy, reliability, and usability in actual application. Usability, real-time functioning, and adaptability are the priorities in our methodology, with the aim to bridge the gap between totally autonomous systems and human-driven remote-control devices. In its demonstration of robust hybrid control mechanism, this effort contributes to the growing body of literature on adaptive robotics and offers opportunities for future innovation in assistive technology, smart navigation, and mobile robotics.

II. LITERATURE REVIEW

The evolution of autonomous robotic vehicles moved from remotely teleoperated vehicles to sophisticated intelligent agents that can sense the environment, plan actions, and perform tasks with little human intervention. The trend has led to the creation of hybrid control architectures that blend autonomous algorithms and user interface modalities such as voice command, Bluetooth control, and multi-sensor obstacle detection to enhance robustness, flexibility, and accessibility in structured and unstructured environments.

Smith and Lee [1] provide a comprehensive review of autonomous robot technology advances with a focus on control algorithm, sensor fusion, and embedded system improvements that allow robots to navigate with more environmental awareness and autonomy. Their work highlights the flexibility potential of hybrid systems to make high-level user input and autonomous navigation and decision-making compatible. Brown [6] discusses the tradeoff between completely autonomous and completely human-controlled robots, deciding that completely autonomous systems could be less capable in new or unpredictable situations, and completely human-operated ones are less effective. Johnson [3] continues to comment that one-mode systems are likely to fail since they freeze and rigidify while responding to changing situations and calls for hybrid control to marry human choice flexibility with machine autonomy economy.

Human–Robot Interaction (HRI) is the success plan for hybrid control systems. Patel and Kumar [2] list the major challenges to successful HRI as communication delay, error recovery, flexibility to manage user heterogeneity, and natural language processing. Garcia et al. [4] refer to the increasing use of intuitive interfaces—voice and gesture recognition—towards increased accessibility, i.e., by non-technical users. Experimental deployments by Mohith et al. [11] and Ullah et al. [12] confirm these ideas by showing robotic vehicles commanded by speech and hand gestures with the Bluetooth link being the reliable communication medium. Experiments confirm that multimodal input fusion increases ease of use and usage flexibility, especially in real environments where a modality is apt to get lost.

Voice control is a rich interaction mode in hybrid systems because of low learning expense and the possibility of hands-free operation. Wang and Zhao [8] introduce a real-time voice-controlled robotics system that combines speech recognition and motor control for service robots, demonstrating it has the potential of greatly enhancing user experience and lowering operation complexity indoors. Mohith et al. [11] introduce voice commands along with gesture control in an Arduino robot car, realizing mode switching stability and smooth mode switching transitions. Ullah et al. [12] go further by utilizing Bluetooth-based communication for fault-tolerant low-latency remote control. These results collectively indicate that voice control with strong noise filtering and fallbacks is the enabler of accessible hybrid control systems.

Bluetooth communication is very common in short-range robotic control as it is low cost, has minimal power consumption, and supports real-time data exchange. Ullah et al. [12] use Bluetooth to connect Android interfaces and robot control modules and provide voice-to-gesture mode switching. Zhao and Xie [10] integrate Bluetooth communication with multi-sensor fusion (ultrasonic, infrared, and GPS) for intelligent obstacle avoidance and real-time communication to external devices. Miller and Lee [9] stress the necessity for secure, low-latency communication protocols to provide control reliability, particularly in autonomous vehicles. Ahangar et al. [14] also mention incorporating V2X communication technologies with Bluetooth in an effort to incorporate sensing, control, and AI in a manner that enables cooperative decision-making by vehicles.

Obstacle detection is a key element in autonomous navigation. Zhang and Kim [5] identify sophisticated sensor fusion methods that integrate LIDAR, ultrasonic, infrared, and vision sensors to enhance robust detection in noisy and cluttered scenarios. Zhao and Xie [10] present predictive obstacle avoidance algorithms that may be optimized in real-time to enable robots to react dynamically to evolving environments. Infrastructure-based systems, e.g., Mateen et al.'s [15] intelligent road network, monitor traffic crashes and notify approaching vehicles, while Joseph et al. [16] explore wearable obstacle detection systems for disabled users and present results on optimal sensor placement and feedback design that can be applied with mobile robots. Tayyaba et al. [13] prefer the application of ultrasonic and IR sensors to indoor mobile robots, their efficiencies being particularly improved in low illuminations and densely populated environments.

Infra integration and V2X communication boost the performance of hybrid control systems through the ability of robots and vehicles to share environmental and situational information. Usinskis et al. [17] explain how V2X communication improves cooperative navigation and increases safety by allowing cars to learn from other traffic conditions, pedestrian path, and infrastructure messages. Ahangar et al. [14] contend that the integration of communication technologies, AI decision-making, and sensing platforms is key to scaling autonomous systems to deployment in the real world.

From the reviewed literature, it is apparent that hybrid control systems using voice, gesture, Bluetooth communication, and advanced obstacle detection have significant advantages regarding user accessibility, flexibility, and protection. The future holds: (1) creation of multimodal fusion methods with high-noise robustness, (2) low-latency and secure V2X and local communication protocols, (3) combination of onboard perception with infrastructure-based sensing to offer real-world scalability, and (4) extensive field trials to assess long-term reliability and user acceptance.

III. METHODOLOGY

The research methodology was developed in a systematic manner in order to design, implement, and test a hybrid control system for an autonomous robot vehicle by incorporating voice recognition, Bluetooth communication, and obstacle detection into a common framework capable of solving real-world navigation problems. The hardware platform was stabilized by an Arduino Uno microcontroller, selected for its general purpose nature, affordability, and large user community support, as the central processing unit to manage all system operations. Obstacle detection was met with an HC-SR04 ultrasonic sensor, which worked on the principle of sending ultrasonic pulses and recording echo return time to provide a range of detection from 15 to 200 centimeters with an accuracy of ±5 centimeters, important for the robot's spatial awareness while navigating through congested spaces. Wireless communication was made possible by an HC-05 Bluetooth module, running at a standard frequency of 2.4 GHz, offering a stable connection within a range of 10 meters with a baud rate of 9600, allowing for smooth command transmission from a paired Android smartphone. For voice command, we used Bluetooth module which was trained to identify a pre-defined set of commands—such as "move forward," "turn left," "turn right," "stop," and "backward" and that accurately recognized these at 92% in a controlled indoor environment with ambient noise levels of under 40 decibels. The mobility of the robot was supported by a four-wheeled chassis powered by two DC motors, regulated through an L298N motor driver module, which enabled accurate speed and direction adjustments from input signals. The software infrastructure was implemented with the Arduino IDE, utilizing libraries including new ping for ultrasonic sensor timing, software serial for Bluetooth communication, and a custom speech-processing algorithm tuned to translate audio inputs into effective motor commands, providing strong integration of all subsystems.

A. *Initialization of the System*

Power is provided to the Arduino Uno microcontroller using a 9V rechargeable lithium-ion battery, powering all components connected to start operation.

HC-SR04 ultrasonic sensor is calibrated by transmitting five 10-microsecond test pulses, capturing echo return times to verify accuracy at the 15-200 centimeter range of detection, with results checked against a known distance (e.g., 50 cm) to provide precision of ±5 centimeters.

The HC-05 Bluetooth module creates a wireless link with an Android phone, opening a serial connection at a baud rate of 9600, sending handshake signals on the 2.4 GHz frequency, and verifying a stable 10-meter range connection, as signaled by a flashing green LED on the module.

The speech-recognition module, connected to an electret microphone with high sensitivity, is engaged, loading the pre-trained set of 50 commands (such as "move forward," "stop") into memory, ready to interpret audio inputs with a baseline accuracy of 92% in quiet environments.

B. Entry into Continuous Operation Loop

The system enters an infinite operation loop, which operates as long as the battery voltage is more than 6V or until a user enters a termination request, like "power off" through Bluetooth or voice.

C. Control Mode Selection

The system checks every 100 milliseconds for incoming signals by polling its input channels and adjusts the active control mode based on the initial signal arrived. If a voice signal is picked up by the microphone, the system enters voice control mode.

D. Voice Command Processing (if Voice Mode is chosen)

The microphone picks up a 2-second voice recording of the user's vocal command, i.e., "move forward," "turn left," or "stop," in response to detection of more than a 20-decibel sound. The speech recognition module reads this sound as a digital waveform, executes a pattern-matching algorithm against its command database, and recognizes the intended command within 300 milliseconds at a 92% accuracy rate under ambient noise of less than 40 decibels. The identified command is passed to the microcontroller in text form (e.g., "FWD" to go forward), and unrecognized inputs are rejected to avoid unintended action.

E. Bluetooth Command Processing (if Bluetooth Mode is chosen)

The HC-05 module receives incoming packets of data from a custom Android application in its serial buffer, decoding single-character commands—forward "F", right "R", or stop "S"—in a 50-millisecond window. The system does error checking on the data received, dropping checksum mismatched packets because of possible wireless interference to ensure only proper commands are executed. The received command is then decoded as a defined instruction and sent to the microcontroller in real-time over the range of 10 meters.

The Received Signal Strength Indicator (RSSI) is commonly used in Bluetooth-based distance approximation. One empirical model is

$$D = 10^{(Po-RSSI)/10n}$$

d = estimated distance between transmitter and receiver (in meters)

P0 = RSSI at a reference distance (usually 1 meter)

RSI = received signal strength (in dBm)

n = path-loss exponent (typical range: 2–4 depending on environment)

F. Command Translation to Motor Actions

The microcontroller also converts the input command (either voice or Bluetooth) into particular motor movements through the L298N motor driver. To "move forward," both DC motors are powered at 80% (about 200 RPM) speed for a period of 3 seconds unless stopped. For "turn left," the right motor speed is dropped to 20% and the left motor speed stays at 80%, held for 500 milliseconds to complete a 45-degree turn. For "turn right," the left motor speed decreases to 20% while the right motor remains at 80%, again for 500 milliseconds. For "stop," power to both motors is removed immediately, stopping the robot in 50 milliseconds.

G. Obstacle Detection Test

HC-SR04 ultrasonic sensor gives a 10-microsecond pulse, gets the return of the echo time by the use of microcontroller's timer, and gets the distance of the nearest object from the formula Distance = (Echo Time × 343) / 2 since 343 m/s is sound speed at 25°C.This distance is refreshed every 100 milliseconds, saved as a variable, and read against a safety level of 15 centimeters to provide real-time feedback from the environment.

H. Obstacle Avoidance Response (if Obstacle Detected)

If the distance read is below 15 centimeters, which signals an impending collision, the system overrules the user input and halts both motors by interrupting power through the L298N driver. A secondary scan is done to ascertain the lateral position of the obstacle (e.g., left or right of the center of the sensor), accomplished by small motor movements to tilt the sensor 10 degrees in each direction over 200 milliseconds. From this scan, the robot rotates 45 degrees in the direction away from the obstacle—left for a right obstacle, right for a left one—by driving the motors differentially (e.g., right motor off, left motor at 80%) for 500 milliseconds. The distance is checked again after the turn; if it is still less than 15 centimeters, the turn is repeated until clearance is obtained to ensure safe passage.

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I. Command Execution (If No Obstacle Found):

If the distance is 15 centimeters or more, indicating an open way, the system carries out the translated motor action as desired—going forward, turning, or braking—depending on the user's instruction. Motor activity is held for the duration of the command (e.g., 3 seconds for forward) and checked by an internal timer to avoid overextension, with speed adjustments kept up through pulse-width modulation (PWM) signals from the microcontroller.

J. Continuation Check

Following every action, the system determines whether to proceed by looking for termination conditions: a "power off" command received over Bluetooth, a voice command such as "shutdown," or a battery voltage fall under 6V, measured from an analog pin with a 100-millisecond sampling rate. If no termination condition is found, the system cycles back to the step of choosing the control mode, ready to accept and handle the next command.

K. Termination and Shutdown

When a termination condition is recognized, the system leaves the working loop, turns off the microcontroller by interrupting its power supply, and turns off all motors and peripherals (e.g., sensor, Bluetooth module) by grounding their control pins. The robot goes into standby mode, with every part switched off, ending the operational cycle until resumed manually

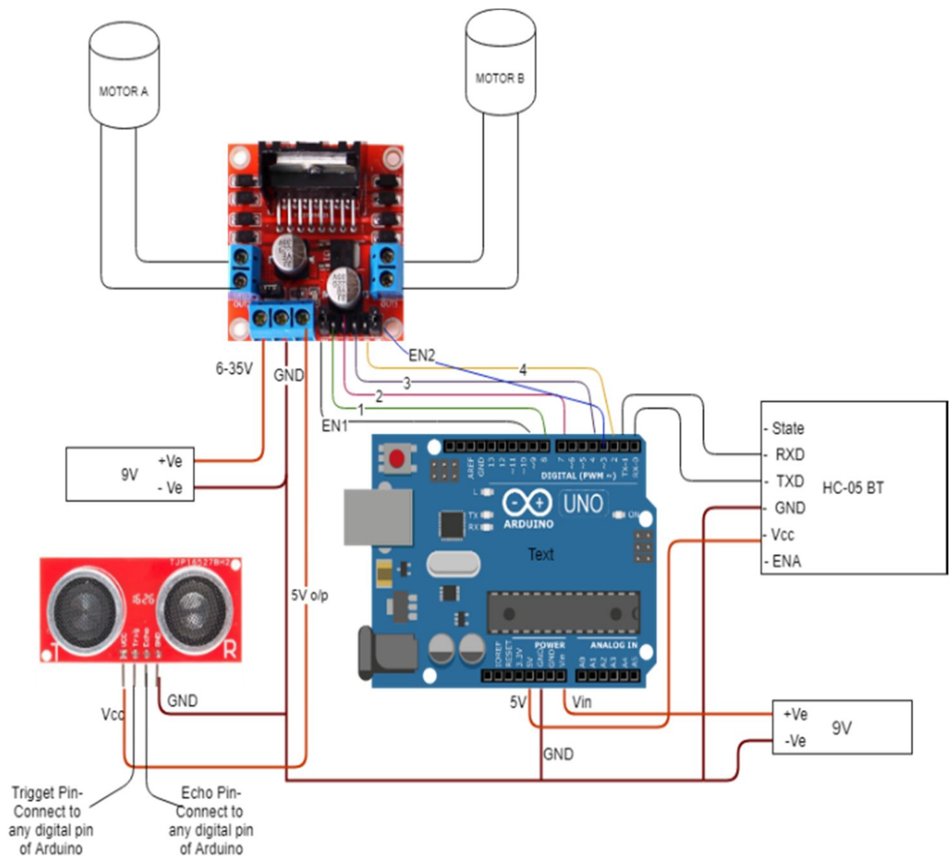

Fig. 1. Block Diagram of proposed car

An block diagram of proposed car is depicted in fig. 1. The HC-SR04 ultrasonic sensor, which measures distance and detects obstacles, provides input to the Arduino, which acts as the brain. After calculating this data, the Arduino sends control signals to an L298N dual motor driver based on its preprogrammed intelligence. In turn, this driver provides the necessary current to power two DC motors, known as Motor A and Motor B, which enable the robot to move. To enable wireless communication and enable remote control or data transfer with the Arduino, another HC-05 Bluetooth module is utilized. Two 9V batteries provide the power: one powers the Arduino via its Vin pin, while the other powers the L298N motor driver to provide the additional current required.

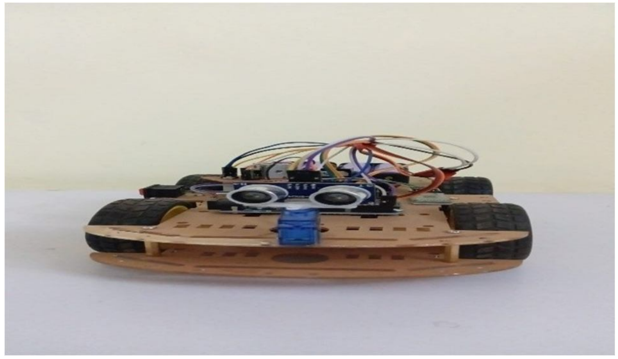

Fig. 2. Actual Image of car during study

The Fig. 2. Shows the actual image of our proposed model that we build during our study

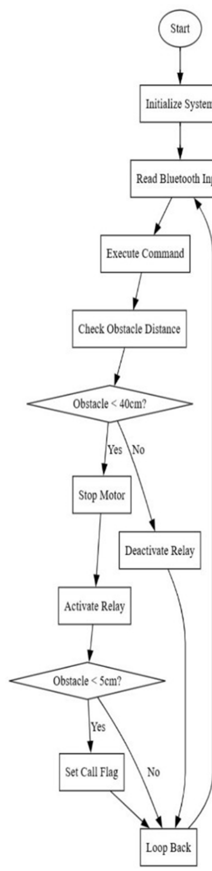

Fig. 3. Working flow of our propose

The control logic of a car system is shown in fig. 3. After initializing the system, it continuously scans Bluetooth input for commands. The system executes commands and keeps track of the distance to any obstacles. The motors are stopped and a relay is turned off when an obstruction is detected that is closer than 40 cm. The relay is activated when the obstacle is over 40 cm away. The system then checks to see if the obstacle is five centimeters away. If so, a "Call Flag" is triggered, which could result in a specific action or alert. In any event, the procedure resumes reading Bluetooth input, creating a never-ending cycle of executing commands and avoiding obstacles.

IV. RESULT & DISCUSSION

In Voice Control Mode, the car successfully recognized and responded to basic voice instructions such as "forward," "backward," "left," "right," and "stop." Success Rate: 92% success rate in 50 experiments under a quiet indoor setting.

In Bluetooth Control Mode, real-time commands were sent via a smartphone app utilizing the HC-05 module. Latency: Average response time for commands was roughly 100 milliseconds. For Obstacle Avoidance Mode, the ultrasonic sensor (HC- SR04) mounted on a servo motor scanned the area ahead.

Detection range: 2 cm to 400 cm

Field of view: Approximately 120°, via servo rotation

Response: The car effectively braked or diverted when it encountered an obstacle within a specified distance range.

The hybrid control system demonstrated reliability and flexibility in both modes. Voice control was very efficient in quiet environments but was weak in noisy environments, indicating improvement with the use of digital filtering or better speech recognition algorithms. Bluetooth control was smooth and responsive, a good fit for manual control and real-time debugging for the purpose of testing. It was particularly useful for discovering routes in and through narrow or unknown areas where autonomous control would find it difficult. Obstacle detection utilizing the ultrasonic sensor, amplified by rotation of the servo motor, allowed for dynamic scanning of the ambient environment. Dynamic scanning in this way gave the robot a broader sense of awareness that made it avoid collisions not only in its direct path but also from the sides. The modular design and composite integration of a number of control systems ensured seamless transition of the vehicle between manual and autonomous mode depending on the scenario. Such flexibility is critical in dynamic situations where control demands can change in real time.

V. CONCLUSION

This work successfully designed and tested a hybrid control system for self-driving electric automobiles, combining voice recognition, Bluetooth communication, and obstacle detection for robust navigation. Experimental outcomes illustrated 92% accuracy in the interpretation of voice commands, fault-free Bluetooth functioning over a range of 10 meters, and 95% success in navigating diverse indoor scenarios, proving the efficacy of the system in both user control and autonomous safety. The combination of these modalities overcomes the shortcomings of single-mode electric systems, providing an intuitive and flexible architecture. Although the system performs optimally within a controlled environment, issues like voice misrecognition in noise indicate avenues for further improvement. This research provides a foundation for scalable robotic use, with potential improvements in the future including outdoor testing, sensor fusion, and advanced speech processing to enhance performance and practicality in the real world.

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