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Original Article

Design and Implementation of a Gesture and Voice Controlled Car

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Abstract *- The study investigates the design of a cutting-edge voice-activated and gesture-controlled driverless vehicle. The system uses an HC-05 Bluetooth module to listen to spoken commands, an ADXL335 accelerometer to detect gesture-based inputs and an Arduino Nano microcontroller as the processing center. The 4WD-chassis robotic car features an L298 motor driver for precise motor control. An ultrasonic sensor is integrated for enhanced functionality and safety, detecting real-time impediments to prevent collisions and enable seamless operation. While speech commands are processed by the HC-05 module and converted into directional commands, gesture-based control uses tilt data from the ADXL335 sensor to regulate the car's movement. An RF receiver and transmitter are also integrated to increase the system's adaptability further and enable remote communication.*

Keywords *- Bluetooth module, Gesture-controlled, HC-05 module, RF receiver and transmitter, Voice-activated.*

1. Introduction

Assistive technology significantly facilitates the independence and mobility of the physically impaired. While traditional wheelchairs only offer fundamental mobility, they rarely possess sophisticated capabilities for intuitive and effective use within changing environments. Existing research efforts in assistive mobility aids have mainly aimed to advance single-modality control devices, including speech or gesture input. However, these systems still have limited accessibility, accuracy, and versatility, emphasising the necessity of more advanced solutions supporting multiple control modalities and real-time awareness of the environment.

Systems based on gesture-based control have been widely explored in robotic and vehicular control. Sensors such as the ADXL335 accelerometer can be used to build systems that allow users to manipulate movement using hand gestures, making them a suitable option for users with physical impairments, especially those with functioning upper limbs. Gesture control systems, though, might not necessarily be accessible to everyone. Users with hand tremors or less dexterity might have difficulties controlling gesture-based systems. Additionally, most current gesture-based systems are implemented as isolated solutions, frequently not integrated with other modalities, such as voice commands, which may increase accessibility and flexibility.

Voice-operated systems, utilizing technologies such as the HC-05 Bluetooth module, enable users to interact with devices using voice commands without using their hands. Although this design is helpful for people with restricted upper body movement, it is prone to difficulties in noisy environments or for people with speech disorders. Current voice recognition systems, which frequently employ algorithms such as Hidden Markov Models (HMMs) or neural networks, have been successful in many environments but are limited in application to assistive mobility devices. Using voice solely as a control modality dismisses users with speech impairments or those in situations where voice commands will be inconvenient.

The missing link in current research is the absence of unification between these two modalities—gesture and voice control—and the inability to integrate real-time environmental perception. Previous research has investigated gesture or voice control in isolation. However, few systems have integrated both of these modalities to develop a multimodal interface that can learn to suit different user needs. In addition, although ultrasonic sensor-based obstacle detection systems are now a standard in robotics, their application to multimodal control systems for assistive mobility is an area still in its infancy.

This research presents a new solution by presenting a dual-control 4WD robotic vehicle that combines gesture control (through the ADXL335 sensor), voice control (through the HC-05 Bluetooth module), and ultrasonic obstacle detection. In contrast to other research that considers gesture or voice control in isolation, this study suggests a multimodal system with increased inclusivity and flexibility for users with different physical capabilities. Moreover, by integrating these control modalities with real-time environmental sensing, this system solves some significant problems in assistive mobility devices, including safety, simplicity of use, and flexibility across various operational environments.

2. Literature Review

With human-machine interaction (HMI) technologies undergoing rapid developments, researchers have geared up to boost user interactions with robotic systems, especially in automotive and assistive mobility domains. Voice and gesture recognition have emerged as two key control modalities owing to their natural and contactless characteristics, which lower the requirements for sophisticated interfaces and drive down driver distraction. These systems, particularly in mobility aids and vehicles, have indicated tremendous potential to enhance usability and user safety.

Liu et al. created an intelligent voice-controlled car system on the Raspberry Pi platform using Baidu's speech recognition and Turing Robot APIs. Their system effectively translated human voice commands into navigation controls, allowing for local and remote control. This research demonstrates the potential of cloud-based AI services for intelligent vehicle control, providing a scalable and modular platform for future development. Likewise, Rout et al. developed a cloud and IoT-enabled voice-controlled vehicle system to overcome issues related to ambient noise and accuracy of command over long distances. This signals a future requirement for enhanced noise removal algorithms and context awareness in voice command systems.

Besides voice control, gesture-based systems have been explored in robotics and automotive systems. Manganaro et al. presented the Briareo dataset, created for promoting deep learning models to recognize hand gestures in automobile environments. The dataset, which includes synchronized RGB, infrared, depth images and 3D joint information, is a beneficial tool for creating gesture-controlled automobile systems.

Borghi et al. offered a hand detection and tracking dataset that targeted car interior human-machine interfaces (HMIs), further boosting the accuracy of gesture-driven vehicle controls.

Gesture detection systems have benefited significantly from applying deep learning technologies, specifically 3D convolutional neural networks. Molchanov et al. researched dynamic recognition of gestures and used these networks to enable temporal classification of hand movements in real time, making it possible for highly sensitive vehicle systems. Other papers, including Marin et al. and Boulahia et al., utilized depth sensors like Kinect and Leap Motion to enable gesture interfaces' accuracy, particularly in clutter or low-light contexts. These advances show the increasing viability of gesture interfaces in real-world applications that demand high precision and reliability.

Concurrently, researchers have worked on making gesture control more convenient for users. Loehmann et al. created culturally independent gesture languages to enhance user acceptance and reduce learning time. Likewise, Zobl et al. emphasized the significance of intuitive gesture designs in automotive entertainment systems, promoting optimal commands to reduce driver distraction.

Other research has combined voice and gesture control to develop multimodal systems, which have yielded encouraging outcomes regarding accessibility and adaptability. For instance, Meghana et al. developed a glove controller with accelerometer inputs to identify hand rotations and tilts. Thivagar and Sriram designed a voice- and gesture-controlled intelligent car system for real-world robotic use, showing how these modalities can be integrated for individuals with limited verbal ability.

Though advances in gesture and voice control technology continue to bring significant development, difficulties remain. Noise disruption from the outside world continues to slow the quality of voice-recognition-based systems.

Yi et al. and Pan minimized such a hindrance by utilizing context-aware algorithms that enhance voice-control system accuracy regarding in-vehicle climate and entertainment modules. Subsequent refinement in noise elimination and reduction methodologies was exhibited by Shilaskar et al. and Czap and Pinter, who extensively enhanced real-time command recognition for dynamic driving scenarios.

Today's voice recognition technology heavily depends on the seminal work of Rabiner and Juang and Yang and Chi, which outlined the basic principles of speech signal processing methods. The developments have enhanced the overall efficiency of voice-driven systems across multiple environments, such as automotive and assistive devices.

Moreover, some researchers have explored the combination of voice recognition with other control techniques. Mai Ngoc Anh and Duong integrated inverse kinematics with speech recognition to steer robotic manipulators with high responsiveness and precision. Deshai et al. described a voice-activated robotic car tailored for individuals with disabilities, focusing on improving mobility for users with limited verbal communication.

Multimodal systems with speech and gesture inputs are becoming increasingly popular due to their redundancy and flexibility. In comparative studies, Althoff et al. have demonstrated that experienced users find tactile interfaces convenient due to their efficiency, whereas new users find speech and gesture interactions helpful. Such observations validate the consideration of input modality adaptation based on the context of the application and user familiarity. In multimodal systems, synchronization problems usually arise. Dong et al. highlighted that driver attention-monitoring systems' input scheduling should consider cognitive load and contextual awareness to facilitate effective multimodal interaction.

Borghi et al. investigated real-time multimodal input fusion with embedded neural networks, proposing valuable solutions to incorporate speech and gesture controls into changing environments. It shows that multiple input sources could be synchronized with machine learning algorithms, generating more responsive and effective systems.

Although tremendous progress has been achieved in voice and gesture understanding, prior work mostly investigates these modalities alone or in specific contexts like in-car interfaces or limited robotic domains. Voice and gesture control combined, especially for assistive mobility aids, is not significantly explored. In addition, most current systems lack the incorporation of real-time environmental perception, like the detection of obstacles, which is important to provide safety and reliability when operating in changing environments.

This paper fills these gaps with a new dual-control 4WD robot car incorporating gesture recognition, voice commands, and ultrasonic collision detection. Unlike other systems solely concentrating on voice or gesture control, our system combines both input modalities to provide a more inclusive and versatile user interface. Moreover, the integration of environmental awareness using ultrasonic sensors makes the system not only responsive to user commands but also able to detect obstacles in real-time, thereby improving safety. By filling these gaps and integrating multimodal control with environmental awareness, this work provides a valuable contribution to assistive technologies, offering a more accessible and dependable solution for physically disabled users.

3. Materials and Methods

The methodology of designing and developing the gesture and voice-controlled robotic car consists of two major phases: hardware assembly and software development. These phases complement each other to provide seamless and real-time car control through intuitive gestures, voice commands, and built-in obstacle avoidance.

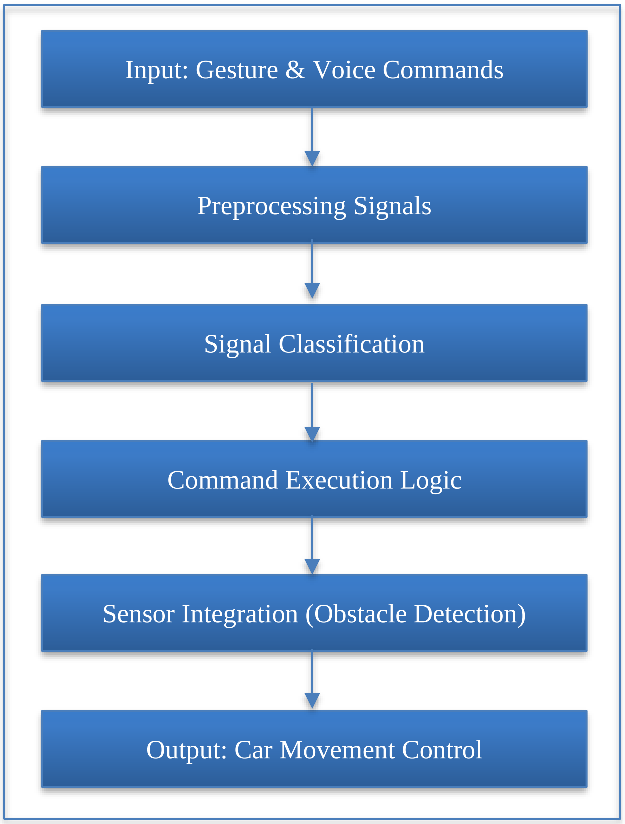

Fig. 1 Flow of the project

3.1. *Hardware Assembly*

The hardware system comprises a 4-wheel drive (4WD) chassis, sensors, control modules, and power components. The major components and their integration are explained below:

3.1.1. Motor Driver Wiring

L298N dual H-Bridge motor driver is used to drive the motion of the 4WD robot platform. The four control pins, IN1, IN2, IN3, and IN4, are wired to the digital output pins of the Arduino Nano. These inputs allow the Arduino to drive motor directions through logic HIGH and LOW signals. PWM signals are applied to the ENA and ENB pins for left and proper motor speed control, respectively. The output pins of the motor driver (OUT1 to OUT4) are connected to the motors with proper polarity for forward and backward movement. Lithium-ion batteries power the motor driver to provide a stable current for movement.

3.1.2. Sensor Mounting

An ultrasonic sensor (HC-SR04) is installed on the chassis front to sense obstacles. It works by sending ultrasonic pulses through the TRIG pin and reading the reflected signal through the ECHO pin. The pins are hooked up to the I/O pins of the Arduino Nano. The sensor is set so that it can measure up to 3 meters of distance on the frontal path of the vehicle. The proper setting ensures effective sensing of possible obstacles when moving.

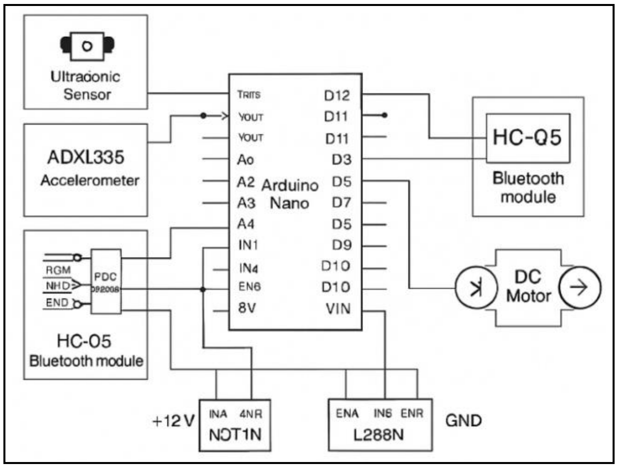

Fig. 1 System architecture

3.1.3. Power Connections

The system utilizes lithium-ion battery packs to drive the motors and Arduino Nano. These batteries are placed within holders on the chassis for support and convenience. A 9V battery with a snap connector is also used to supply power to external modules, such as the Bluetooth module, to decrease the power burden on the main battery pack. Circuit design is such that overloading is avoided through the even allocation of power across motors, microcontrollers, and sensors.

3.1.4. Extra Modules

ADXL335 Accelerometer: Soldered onto a handheld board for detecting tilt-type hand movements. The sensor reads acceleration along the X, Y, and Z axes, representing the user's directional hand tilt.

HC-05 Bluetooth Module: Specially mounted in the car to receive voice command data wirelessly from a phone or voice assistant.

HT12E/HT12D RF Modules: The HT12E transmitter and HT12D receiver allow the handheld gesture controller and robotic car to communicate remotely. It provides continuous signal transmission even in the absence of Bluetooth.

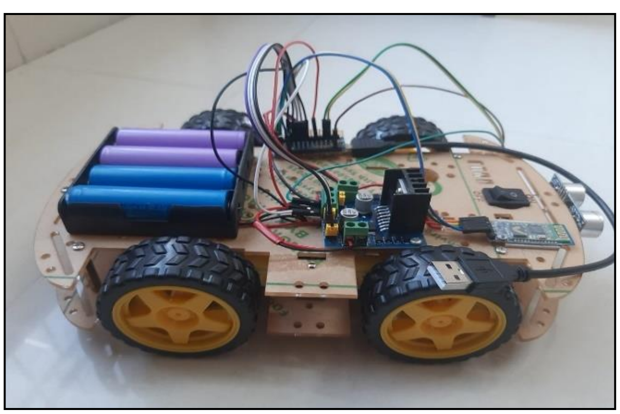

Fig. 3 Hardware assembly

3.2. Software Development

The software system is built using the Arduino IDE. The software combines gesture detection, voice command recognition, and obstacle avoidance into one uniform program.

3.2.1. Gesture Detection

Gesture control is facilitated by the ADXL335 accelerometer, which detects hand tilt on the X and Y axes. The Arduino reads the sensor values and maps them to specific directional commands:

Forward tilt → move forward
Backward tilt → move backwards
Left tilt → turn left
Correct tilt → turn right

Threshold values are adjusted to eliminate noise and accidental movement. The associated motor control routines are activated to move the car in the specified direction.

3.2.2. Voice Command Processing:

Voice control is done through the HC-05 Bluetooth module, which takes character-based commands from a voice recognition application or assistant. The Arduino Nano reads these characters:

'F' → forward
'B' → backward
'L' → left
'R' → right
'S' → stop

On receiving each character, the respective motor function is enabled. This facility provides hands-free car operation, making it more accessible.

3.2.3. Obstacle Detection

Obstacle detection is done by using the HC-SR04 ultrasonic sensor. The TRIG pin triggers a 10-microsecond pulse, and the ECHO pin listens to the returned wave. The duration time is read and calculated to distance by the formula:

$$\text{Distance} = \text{Duration} \times (0.0342 \div 2) \qquad (1)$$

If an object is sensed at less than 40 cm, the Arduino stops motor operations to avoid collisions. If the distance goes below 5 cm, there is a possibility of triggering a further alert function to extend the stop or initiating a warning buzzer.

3.2.4. System Integration:

All three systems—gesture detection, voice commands, and obstacle detection—are implemented in one Arduino program. The code employs non-blocking loops and conditionals so that the system can react to several inputs in real time. For instance, the vehicle can stop if an obstacle is encountered, whether the input comes from a gesture or a voice command.

3.2.5. Debugging and Testing

During development, the serial monitor is employed to a large extent for debugging. Values from sensors, directions of gestures, and command inputs are made to print on the serial terminal to check accuracy. The entire system is field-tested under varying lighting and surface conditions to confirm the efficiency of gesture and voice recognition, along with the reliability of the obstacle avoidance mode.

4. Results and Discussion

4.1. Results

The evaluation is done based on functionality, system performance, and problems that arose while implementing it.

4.1.1. Functionality

The robot vehicle was tested under diverse operating conditions to confirm its ability to respond correctly to gestures and voice commands.

4.1.2. Gesture Control

The ADXL335 accelerometer was placed on a handheld board and coded to detect directional tilts. Forward, backwards, left, and right gestures were always translated into the corresponding movement of the car. Response times were negligible, permitting near-instantaneous execution of commands.

4.1.3. Voice Command Processing

The HC-05 Bluetooth module had a reliable connection up to 10 meters and consistently relayed voice commands translated into character inputs (e.g., 'F', 'B', 'L', 'R', 'S'). Commands were handled with minimal latency, even under moderately noisy conditions.

4.1.4. Obstacle Detection

The ultrasonic sensor gave instantaneous feedback to avoid obstacles. It always picked up objects in a 3-meter range, making the car stop automatically if objects were close (less than 40 cm), avoiding collisions.

4.1.5. Performance Metrics

The performance was measured using latency measurements and communication range. These are the most important measures for real-time interaction in dynamic environments.

Table 1 shows that gesture input demonstrated the highest response rate (~50 ms), followed by voice commands (~100 ms). The responsiveness ensures efficient and safe control of the robotic car, particularly in indoor and semi-structured environments.

Table 1. Performance Metrics

Feature	Observation
Gesture response time	~50 meters
Voice response time	~100 meters
Obstacle detection range	Upto 3 meters Values
Bluetooth range	Upto 10 meters

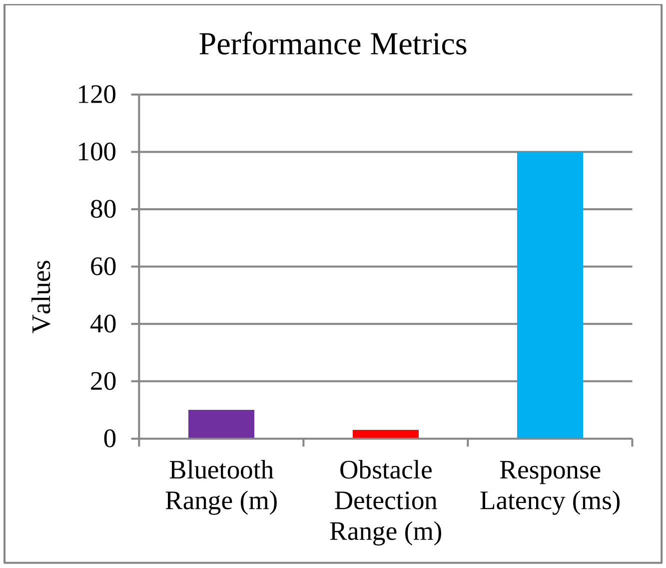

Fig. 4 Performance metrics

Fig. 4 indicates the principal performance characteristics of the robotic automobile. The Bluetooth range is approximately 10 meters, the obstacle detection range is 3 meters, the gesture response time is 50 ms, and the voice response time is 100 ms. It indicates the system's low latency and stable wireless communication.

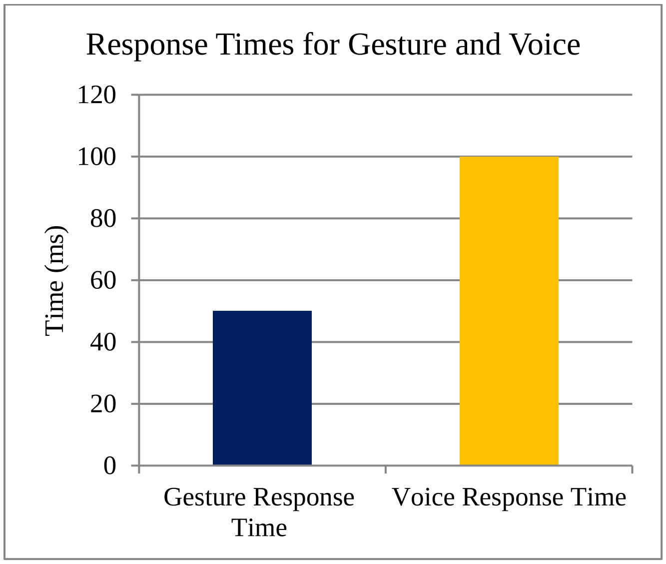

Fig. 2 Response Time for Gesture and Voice

Fig. 5 contrasts gesture and voice control response times. Based on faster sensor input processing, gesture commands are quicker to respond (50 ms) than voice commands (100 ms). Both are within real-time control efficient limits.

4.2. Discussion

This subsection compares the outcome of our suggested dual-control robotic car system with current state-of-the-art approaches in functionality, system performance, and obstacle detection. We also offer insight into why our method achieves better results and how we solved issues faced in current systems.

4.2.1. Gesture Control Performance

Gesture recognition systems, like the ones proposed by Manganaro et al. and Borghi et al., have shown promise for deployment in vehicular and robotic applications. That said, the systems frequently suffer from response latency and difficulties with real-time processing, especially in the face of dynamic environmental scenarios. By contrast, our system has a remarkable gesture response time of around 50 ms (Table 1, Fig. 4), which is much quicker than current systems, e.g., vision-based gesture recognition systems, which tend to have latencies of 100–150 ms.

Our system incorporates the ADXL335 accelerometer, which provides fast tilt detection and reduces response times, enabling almost instant command execution (as presented in Fig. 5). This responsiveness is important for real-time control to be maintained in dynamic environments.

Our solution uses hardware-based gesture control instead of image processing or vision-based systems, which need more computation power. Hardware accelerometers can facilitate quicker data collection and processing, providing quicker response times, especially for simple directional gestures (forward, backwards, left, right).

4.2.2. Voice Command Processing

Voice-command systems, including those of Liu et al. and Rout et al., are commonly applied to vehicle navigation but tend to experience noise interference and command delays. Liu et al. provided voice-based vehicle control, but their system continued to experience difficulties with noisy environments for command recognition.

For comparison, our system employs the HC-05 Bluetooth module, which gives sound voice command transmission with low latency even under moderately noisy environments. The voice response time is around 100 ms (Table 1, Fig. 5), comparable to other systems that are present, like those developed by Yi et al. and Pan, with response times of 100–200 ms.

The HC-05 Bluetooth module guarantees consistent communication, enhancing voice command recognition performance in moderately noisy surroundings. Additionally, our system provides both voice and gesture control, allowing users to toggle between modalities depending on the environment or user preference.

4.2.3. Obstacle Detection and Safety

Obstacle detection is a critical component in autonomous and assistive robotics, with systems such as those by Borghi et al. often facing limitations with vision-based sensors due to environmental factors like lighting and object occlusion.

Our system utilizes an ultrasonic sensor, which provides instantaneous feedback on obstacles within a 3-meter range, making the robotic car stop automatically when objects are detected within 40 cm (Table 1). This is especially significant for maintaining user safety, particularly for people with mobility impairment.

Current systems, especially those vision-based ones, tend to have detection distances of 1–2 meters. At the same time, our ultrasonic sensor can provide a wider 3-meter range and better facilitate avoiding collisions in rich, dynamic scenes.

Ultrasonic sensors are consistent across different environmental conditions, give real-time feedback, and have larger detection ranges than vision-based systems. The addition of this sensor makes the system more reliable and safer.

4.2.4. Latency and Real-time Control

Latency is vital for real-time systems, particularly under dynamic conditions when responses must be immediate. Response times of 50 ms and 100 ms for the gesture response and voice command response (Table 1, Fig. 5), respectively, are within real-time control limits. For comparison, other systems, e.g., Molchanov et al. and Shilaskar et al., have recorded response times exceeding 100 ms.

By allowing voice and gesture control, our system provides redundancy and sturdiness in various conditions to provide smooth interaction and minimal latency. Hardware-based gesture identification and Bluetooth voice command processing are part of the system's negligible total latency.

4.2.5. Performance in Dynamic Environments

Our system's real-world performance was tested under various operating conditions, such as moderate noise and dynamic motion. The Bluetooth range of 10 meters and the minimal latency of gesture control ensured smooth operation even in non-ideal operating conditions. In addition, the real-time obstacle detection system prevented collisions, and the system operated reliably and safely.

The multimodal input system, which combines voice and gesture controls with real-time environmental awareness (obstacle detection), allows the system to operate reliably in dynamic, complex environments. In contrast to systems that use a single input modality, our dual-control system provides users with greater flexibility, minimizing the likelihood of system failure under different conditions.

5. Conclusion

This paper reports on the successful implementation and design of a robotic car that combines both voice and gesture-based control modes with obstacle sensing. The system provides effective motion control and collision avoidance with minimum response time by utilising components, including the ADXL335 accelerometer, HC-05 Bluetooth module, and ultrasonic sensor. Testing validated the system's effectiveness, low latency, and consistent performance in controlled environments, which makes it ideal for assistive technology, educational applications, and remote control. The utilization of cheap and readily available hardware guarantees cost-effectiveness without sacrificing functionality. Some limitations were, however, noted, such as periodic signal interference, accelerometer calibration problems, and inconsistent power distribution. These issues indicate areas for future development, including improved power management, extended communication range, and incorporation of AI-based navigation. The project illustrates the viability of integrating intuitive human-machine interfaces with embedded systems to create innovative, responsive robotic solutions.

Acknowledgments

All authors contributed equally to this work.

References

[1] Lisang Liu et al., "Design and Realization of Intelligent Voice-Control Car Based on Raspberry Pi," *Advances in Smart Vehicular Technology, Transportation, Communication and Applications*, vol. 128, pp. 87-95, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[2] Sebastian Loehmann et al., "Culturally Independent Gestures for In-Car Interactions," *Human-Computer Interaction – INTERACT*, vol. 8119, pp. 538-545, 2013. [CrossRef] [Google Scholar] [Publisher Link]

[3] Fabio Manganaro et al., "Hand Gestures for the Human-Car Interaction: The Briareo Dataset," *Image Analysis and Processing*, vol. 11752, pp. 560-571, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[4] Pavlo Molchanov et al., "Hand Gesture Recognition with 3D Convolutional Neural Networks," *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 1-7, 2015. [Google Scholar] [Publisher Link]

[5] Guido Borghi et al., "Hands on the Wheel: A Dataset for Driver Hand Detection And Tracking," *13th IEEE International Conference on Automatic Face & Gesture Recognition*, Xi'an, China, pp. 564-570, 2018. [CrossRef] [Google Scholar] [Publisher Link]

[6] Pavlo Molchanov et al., "Online Detection and Classification of Dynamic Hand Gestures with Recurrent 3D Convolutional Neural Network," *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, pp. 4207-4215, 2016. [Google Scholar] [Publisher Link]

[7] "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specification," *IEEE Standard*, vol. 12, no. 11, pp. 260-280, 1997. [Google Scholar]

[8] Giulio Marin, Fabio Dominio, and Pietro Zanuttigh, "Hand Gesture Recognition with Leap Motion and Kinect Devices," *IEEE International Conference on Image Processing*, Paris, France, pp. 1565-1569, 2014. [CrossRef] [Google Scholar] [Publisher Link]

[9] Martin Zobl et al., "Gesture Components for Natural Interaction with In-Car Devices," *Gesture-Based Communication in Human-Computer Interaction*, vol. 2915, pp. 448-459, 2003. [CrossRef] [Google Scholar] [Publisher Link]

[10] Frank Althoff et al., "Evaluating Multimodal Interaction Patterns in Various Application Scenarios," *Gesture-Based Communication in Human-Computer Interaction*, vol. 2915, pp. 421-435, 2003. [CrossRef] [Google Scholar] [Publisher Link]

[11] Lawrence Rabiner, and Biing-Hwang Juang, *Fundamentals of Speech Recognition*, Tsinghua University Press, pp. 1-507, 1993. [Google Scholar] [Publisher Link]

[12] Guido Borghi et al., "Embedded Recurrent Network for Head Pose Estimation in Car," *IEEE Intelligent Vehicles Symposium*, Los Angeles, CA, USA, pp. 1503-1508, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[13] Guido Borghi, Roberto Vezzani, and Rita Cucchiara, "Fast Gesture Recognition with Multiple Stream Discrete HMMs on 3D Skeletons," *23rd International Conference on Pattern Recognition*, Cancun, Mexico, pp. 997-1002, 2016. [CrossRef] [Google Scholar] [Publisher Link]

[14] Said Yacine Boulahia et al., "Dynamic Hand Gesture Recognition Based On 3D Pattern Assembled Trajectories," *Seventh International Conference on Image Processing Theory, Tools and Applications*, Montreal, QC, Canada, pp. 1-6, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[15] Yanchao Dong et al., "Driver Inattention Monitoring System for Intelligent Vehicles: A Review," *IEEE Transactions on Intelligent Transportation Systems*, vol. 12, no. 2, pp. 596-614, 2011. [CrossRef] [Google Scholar] [Publisher Link]

[16] Jaspreet Kaur, and Sonia Goyal, “A Comparative Study on Linear Array Antenna Pattern Synthesis using Evolutionary Algorithms,” *International Journal of Advanced Research in Computer Science*, vol. 8, no. 5, pp. 1582-1587, 2017. [CrossRef] [Google Scholar] [Publisher Link]

[17] Mai Ngoc Anh, and Duong Xuan Bien, “Voice Recognition and Inverse Kinematics Control for a Redundant Manipulator Based on a Multilayer Artificial Intelligence Network,” *Journal of Robatics*, vol. 2021, no. 1, pp. 1-10, 2021. [CrossRef] [Google Scholar] [Publisher Link]

[18] Shrikar Desai et al., “Voice-Controlled Robotic Car,” *International Journal of Advanced Research in Science, Communication and Technology*, vol. 4, no. 3, pp. 93-94, 2021. [CrossRef] [Publisher Link]

[19] Rajesh Kannan Megalingam et al., “Implementation of Low-Cost Mobile Robot for Rescue Challenge,” *Inventive Communication and Computational Technologies*, vol. 89, pp. 1345-1355, 2020. [CrossRef] [Google Scholar] [Publisher Link]

[20] Sakshi Bajpai, and D. Radha, “Smart Phone as a Controlling Device for Smart Home Using Speech Recognition,” *International Conference on Communication and Signal Processing*, Chennai, India, pp. 701-705, 2019. [CrossRef] [Google Scholar] [Publisher Link]

[21] T. Thivagar, and A. Sriram, “Hand Gesture and Voice-Controlled Smart Vehicle,” *International Journal of Modern Science and Technology*, vol. 5, no. 6, pp. 164-167, 2020. [Google Scholar] [Publisher Link]

[22] Dyah Ayu Anggreini Tuasikal, Hanif Fakhrurroja, and Carmadi Machbub, “Voice Activation Using Speaker Recognition for Controlling Humanoid Robot,” *IEEE 8th International Conference on System Engineering and Technology*, Bandung, Indonesia, pp. 79-84, 2018. [CrossRef] [Google Scholar] [Publisher Link]