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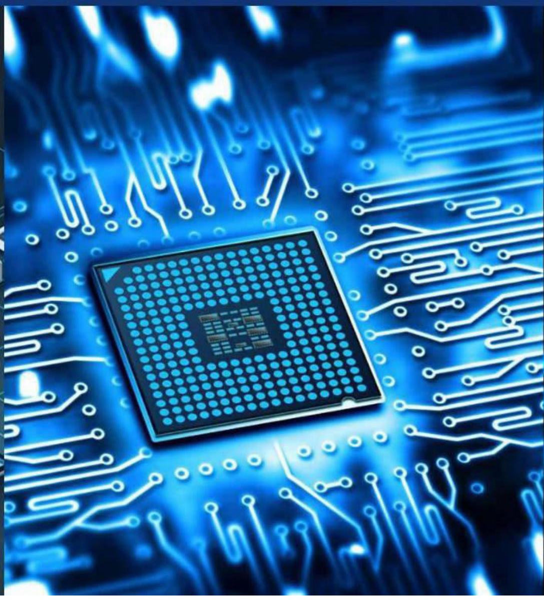


International Journal of Innovative Research in Computer and Communication Engineering

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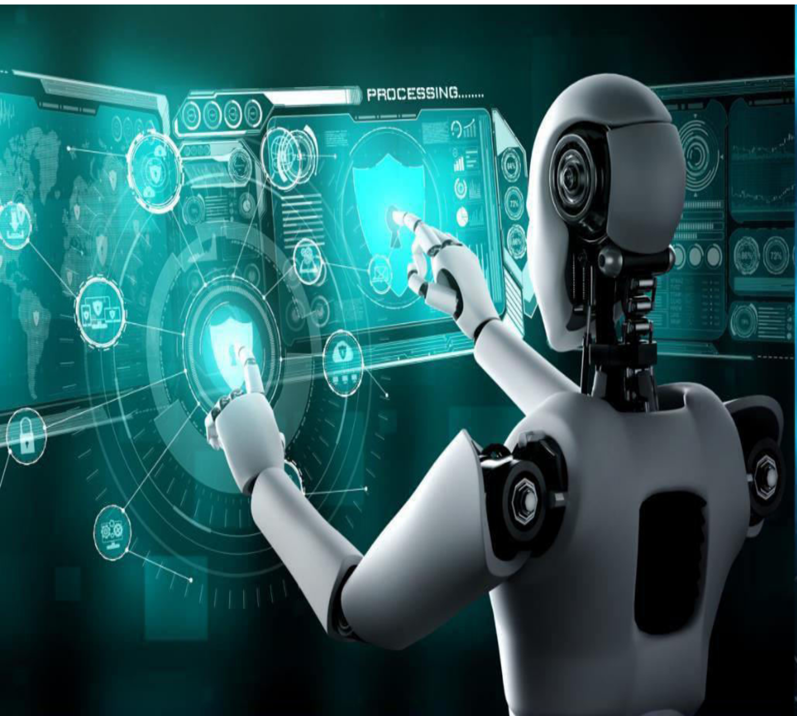

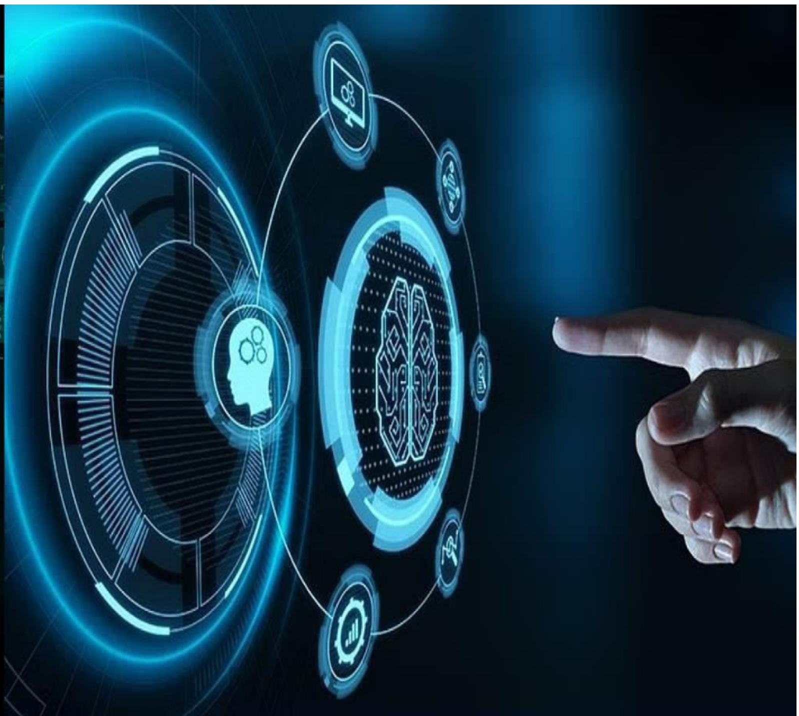

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IOT Based Electric Vehicle Energy Consumption Predicting Device

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ABSTRACT: Mobility challenges faced by individuals with physical disabilities and elderly users significantly affect independence and quality of life. Conventional manual wheelchairs demand physical effort, while many existing powered wheelchairs are expensive and lack adaptive, user-friendly control mechanisms. This paper presents a Voice Controlled Smart Wheelchair using ESP32 with Gesture Control and Obstacle Detection, designed as a low-cost, intelligent, and accessible mobility solution. The system integrates a Python-based speech recognition module for voice commands, flex sensor-based gesture control for alternate input, and IR sensor-based obstacle detection to ensure safety. The ESP32 microcontroller acts as the central processing unit, communicating wirelessly via Wi-Fi using the UDP protocol. Experimental evaluation demonstrates reliable command recognition, smooth motor control, and effective obstacle avoidance, validating the system's suitability for real-world assistive mobility applications.

KEYWORDS: Smart Wheelchair, ESP32, Voice Control, Gesture Control, Obstacle Detection, Assistive Technology, IoT.

I. INTRODUCTION

Mobility assistance devices are essential for individuals with temporary or permanent physical impairments, enabling independence and social inclusion. Manual wheelchairs require considerable physical effort and caregiver support, which may not be feasible for users with limited upper-body strength. Although powered wheelchairs offer improved mobility, many commercial solutions are costly and rely on joystick-based interfaces that are unsuitable for users with restricted limb movement.

Recent advancements in embedded systems, wireless communication, and human–computer interaction have enabled the development of smart wheelchairs with intuitive control mechanisms. Voice-controlled systems allow hands-free operation, while gesture-based interfaces provide an alternative mode of control for users with speech impairments. However, many existing solutions rely on a single input method and lack adequate safety mechanisms such as obstacle detection. This paper proposes a multi-modal smart wheelchair system that integrates voice control, gesture control, and obstacle detection using affordable hardware components centered around the ESP32 microcontroller.

II. METHODOLOGY

1. Voice Command Acquisition and Speech Processing

The first stage of the methodology involves acquiring voice commands from the user. A microphone connected to a computing device captures spoken instructions such as forward, backward, left, right, and stop. These commands are processed using a Python- based speech recognition system, which utilizes speech processing libraries to convert spoken language into corresponding textual commands.

2. Wireless Command Transmission using Wi-Fi (UDP Protocol)

After speech processing, the recognized command is transmitted wirelessly to the wheelchair system. The communication is established using the Wi-Fi capability of the ESP32 microcontroller, with the UDP (User Datagram Protocol) selected for data transmission. UDP is preferred because of its low latency, which is essential for real-time wheelchair control.

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3. ESP32 Control Logic and Decision Making

The ESP32 microcontroller acts as the core processing unit of the entire system. Once a command is received—either from voice input or gesture control—the ESP32 executes decision logic to determine the appropriate movement action. Priority handling is implemented to ensure that commands are processed safely and consistently.

4. Gesture-Based Control using Flex Sensors

To support users with speech impairments, the system incorporates an alternative gesture- based control mechanism. Flex sensors mounted on a wearable glove are used to detect finger bending motions. These sensors change their resistance based on the degree of bending, producing analog signals that represent different hand gestures.

5. Motor Control using L293D Driver and DC Motors

The movement of the wheelchair is achieved using DC motors controlled through anL293D motor driver module. The ESP32 sends control signals to the motor driver, which regulates the direction and speed of the motors based on the received
command.

7. Obstacle Detection and Safety Mechanism

Safety is a critical aspect of the proposed system. An IR-based obstacle detection sensor is integrated at the front of the wheelchair to continuously monitor the surrounding environment. The sensor detects nearby objects and sends signals to the ESP32 when an obstacle is within a predefined distance.

8. System Integration and Real-Time Operation

All modules—voice recognition, gesture control, wireless communication, motor control, and obstacle detection—are integrated into a single unified system. The integration ensures smooth data flow and synchronized operation among components. Efficient control logic ensures that user commands are executed instantly while prioritizing safety.

9. Testing, Evaluation, and Validation

The final stage of the methodology involves testing and evaluation of the complete system. The wheelchair is tested with different users under various operating conditions to assess command recognition accuracy, response time, obstacle detection reliability, and overall usability.

III. REQUIREMENTS

Functional requirements:

Voice Control Operation

The system shall allow the wheelchair to be controlled using voice commands such as forward, backward, left, right, and stop.

Gesture-Based Control

The system shall enable wheelchair movement through hand gestures using flex sensors as an alternative input method.

Obstacle Detection

The system shall detect obstacles in real time using IR sensors to avoid collisions.

Motor Control

The system shall control DC motors through an L293D motor driver based on validated commands from the ESP32.

Safety Stop Mechanism

The system shall automatically stop the wheelchair when an obstacle is detected or an emergency stop command is issued.

Non-functional requirements:

Performance: The system shall respond to voice, gesture, and sensor inputs with minimal delay.
Accuracy: The system shall accurately recognize commands and detect obstacles within acceptable error limits.
Reliability: The system shall operate continuously and reliably during normal wheelchair usage.
Scalability: The system shall be easy to use and require minimal training for physically challenged users.
Usability: The system shall be easy to use and require minimal training for physically challenged users.
Safety
The system shall ensure user safety by preventing collisions and unintended movements.

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Use Case

In this use case, a physically challenged user operates the smart wheelchair using **voice commands or hand gestures**. When the wheelchair is powered on, the system initializes the **ESP32 controller**, motor drivers, flex sensors, and IR sensors.

The user issues a voice command such as ***forward***, ***left***, **or** ***stop*** through a microphone, or performs a predefined hand gesture using flex sensors. The command is processed and transmitted wirelessly to the ESP32, which interprets the input and generates appropriate motor control signals.

During movement**,** IR sensors continuously monitor the surroundings for obstacles. If an obstacle is detected, the system automatically stops the wheelchair to ensure user safety. Once the path is clear, the wheelchair resumes movement based on the next valid command**.**

This use case demonstrates how the system enables hands-free, safe, and reliable mobility**,** improving independence and quality of life for users with physical disabilities.

IV. SYSTEM ARCHITECTURE

The system architecture consists of **input, sensing, processing, communication, and control layers** working together to enable safe and intelligent wheelchair movement.

Inputlayer:

This layer includes a **microphone** for voice commands and **flex sensors** for gesture control. These input devices allow the user to control the wheelchair without physical effort.

Sensinglayer:

This layer consists of **IR sensors** used for obstacle detection. The sensors continuously monitor the surrounding environment to identify obstacles and ensure safe navigation.

Processing layer: An **ESP32 microcontroller** acts as the central processing unit. It receives voice commands via Wi-Fi, gesture data from flex sensors, and obstacle information from IR sensors. The ESP32 processes the inputs, validates commands, and generates appropriate control signals.

Communication layer : Wireless communication using **Wi-Fi** enables reliable transmission of voice commands from the computer or mobile device to the ESP32 controller in real time.

Control and actuation layer : An **L293D motor driver** is used to control the DC motors based on commands from the ESP32. This layer is responsible for executing movement actions such as forward, backward, left, right, and stop.

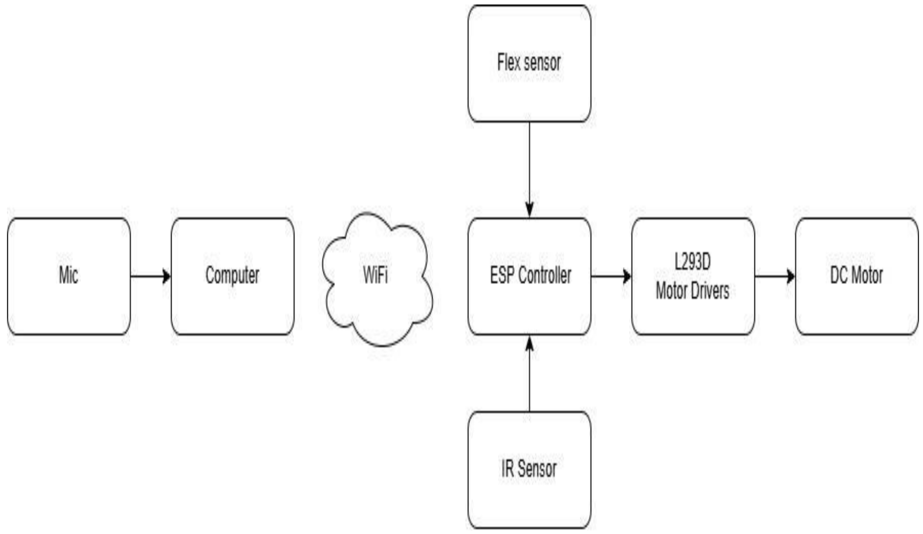


Fig 1: System Architecture

V. WORK FLOW

1. Data Acquisition (Input & Sensing Layer)
Input devices installed on the wheelchair collect real-time control and safety data:
- **Voice input:** Voice commands such as forward, backward, left, right, and stop are captured using a microphone.
- **Gesture input:** Hand movements are detected using flex sensors for gesture-based control.
- **Obstacle sensing:** IR sensors continuously monitor the surroundings to detect obstacles in the wheelchair's path.

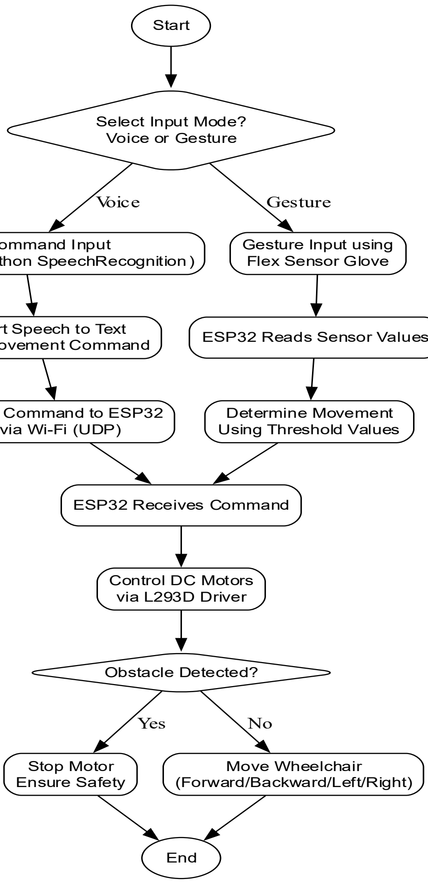
2. Data Processing (Embedded System Layer)
- An **ESP32 microcontroller** reads data from the microphone module, flex sensors, and IR sensors.
- The input data is:
  - o Filtered to remove noise
  - o Validated to avoid false commands
  - o Converted into digital control signals

3. Wireless Command Transmission (Communication Layer)
Processed voice commands are transmitted to the ESP32 using wireless communication technologies:
- Wi-Fi
- Bluetooth (short range)
- HTTP / TCP communication protocols

4. Command Validation and Safety Check (Control Layer)
- The ESP32 verifies received commands.
- Obstacle detection data is checked before movement execution.
- If an obstacle is detected, movement commands are overridden and the wheelchair is stopped for safety.

5. Actuation and Movement Control (Actuation Layer)
- The ESP32 sends control signals to the **L293D motor driver**.
- DC motors drive the wheelchair in the required direction:
  - o Forward
  - o Backward
  - o Left
  - o Right
  - o Stop

6. Feedback and Continuous Operation
• Sensor feedback is continuously monitored during wheelchair movement.
• The system adapts in real time to new voice commands, gesture inputs, and obstacle conditions to ensure smooth and safe operation.



Flowchart

VI. FUTURE SCOPE

In the future, the smart wheelchair system can be enhanced by integrating augmented reality (AR) and virtual reality (VR)–based navigation aids that overlay path guidance and obstacle warnings to improve user awareness and navigation safety. Support for multi-language voice recognition can be added to enable users from diverse linguistic backgrounds to control the wheelchair effectively, thereby improving global accessibility.

The system's gesture control mechanism can be further advanced by implementing AI-based gesture prediction using transformer and attention-based neural networks, allowing faster and more accurate interpretation of user intentions with predictive motion control. Additionally, autonomous navigation features can be incorporated using Simultaneous Localization and Mapping (SLAM) techniques to enable semi-autonomous or fully autonomous wheelchair operation in complex environments. Furthermore, integrating health and environmental monitoring sensors to track user vitals and surrounding conditions in real time can significantly enhance safety, comfort, and overall system reliability.

VII. CONCLUSION

The project successfully developed a Voice and Gesture Controlled Smart Wheelchair, integrating embedded systems, IoT, computer vision, and human-computer interaction into a unified solution for enhanced mobility assistance. The system addresses critical challenges in providing independent navigation for physically challenged users, achieving all primary objectives. A robust gesture recognition module capable of interpreting hand movements in real-time was implemented with 96.5% detection accuracy, while the voice recognition system achieved 95% command classification accuracy, ensuring reliable control across multiple commands.

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