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Voice Assist Using ESP 32

[1]Mufid Shaikh, [2]Omkar Chemate, [3]Vaishnavi Pataskar, [4]Sachin Kokane

[1,2,3]Student, Electronics and Telecommunication Engineering, AISSMS IOIT, Pune, Maharashtra, India

[4]Associate Professor, Electronics and Telecommunication Engineering, AISSMS IOIT, Pune, Maharashtra, India

***Abstract* - Voice-controlled automation systems are gaining popularity in smart home technologies due to their convenience and ease of use. This project presents a Voice Assist ESP system, which enables users to control multiple electrical appliances using voice commands. The system is built around the ESP32 WROOM microcontroller, which acts as the central processing unit. Voice commands such as *fan on/off, LED on/off, buzzer on/off, and light on/off* are given through a smartphone application and transmitted to the system using the HC-05 Bluetooth module. The ESP32 receives these commands and processes them to control different appliances connected through a 4-channel relay module. The received command and device status are displayed on a 16×2 LCD display to provide real-time feedback to the user. Additionally, the ESP32 utilizes its built-in Wi-Fi capability to upload device status and command data to a cloud IoT platform, enabling remote monitoring and data logging. The proposed system offers a cost-effective, reliable, and user-friendly solution for smart automation. It improves convenience and accessibility, especially for elderly or physically challenged individuals, by allowing hands-free control of household appliances.**

Keywords: Voice Control, ESP32, HC-05 Bluetooth Module, Smart Home Automation, IoT, Relay Module, LCD Display.

I. INTRODUCTION

The rapid development of Internet of Things (IoT) technology has significantly transformed the way people interact with electronic devices and household appliances. In modern homes and industries, automation systems are increasingly used to improve convenience, efficiency, and energy management. Traditional electrical systems require manual operation through switches, which can be inconvenient and time-consuming. Moreover, manual control may be difficult for elderly individuals and physically challenged people. To overcome these limitations, smart automation systems that allow remote or voice-based control of appliances have gained considerable attention.

Voice-controlled technology has emerged as one of the most natural and user-friendly methods of interacting with electronic systems. Instead of manually operating switches, users can simply give voice commands to control devices. With the integration of wireless communication technologies such as Bluetooth and Wi-Fi, voice commands can be transmitted to embedded systems that process the commands and perform the required actions. These technologies enable the development of intelligent systems capable of controlling appliances efficiently and reliably.

Microcontrollers play a crucial role in implementing such smart systems. Among them, the ESP32 WROOM microcontroller has become highly popular due to its powerful processing capability, built-in Wi-Fi and Bluetooth support, and low power consumption. The ESP32 can easily communicate with external devices and cloud platforms, making it ideal for IoT-based automation projects. By integrating the ESP32 with communication modules and sensors, real-time control and monitoring of devices can be achieved.

In this project, a Voice Assist ESP system is developed to control electrical appliances using voice commands. The system uses an HC-05 Bluetooth module to receive commands from a smartphone application that converts speech into text. These commands are transmitted to the ESP32 microcontroller, which processes the received instructions and activates the corresponding devices. A 4-channel relay module is used to control different appliances such as a fan (motor), LED, buzzer, and bulb. The relay module acts as an electrically operated switch that allows low-power microcontroller signals to control high-power devices safely.

To enhance user interaction and provide real-time feedback, a 16×2 LCD display is used to show the received voice commands and the status of the appliances. This allows the user to verify whether the system has correctly interpreted the command. Additionally, the ESP32 utilizes its built-in Wi-Fi capability to upload device status information to a cloud-based IoT platform, enabling remote monitoring and data logging. This feature makes the system more intelligent and capable of providing real-time updates from anywhere with internet connectivity.

The integration of voice recognition, Bluetooth communication, embedded systems, and IoT technology provides a powerful and flexible solution for modern smart home applications. The proposed system is designed to be simple, cost-effective, and easy to implement while offering efficient control of electrical appliances. By enabling voice-

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based operation and IoT monitoring, the system improves convenience, accessibility, and overall user experience.

Therefore, the Voice Assist ESP project demonstrates how voice command technology combined with IoT-enabled microcontrollers can be used to create an effective smart automation system. Such systems have wide applications in smart homes, offices, and assistive technologies, contributing to the development of more intelligent and connected environments.

II. LITERATURE REVIEW

Recent advancements in Internet of Things (IoT) and embedded systems have enabled the development of smart home automation systems that allow users to control appliances through wireless communication and voice commands. Researchers have explored various technologies such as ESP32 microcontrollers, Bluetooth modules, Wi-Fi connectivity, and cloud platforms to improve the efficiency and usability of home automation systems.

Roy *et al.* developed a voice-controlled home automation system that allows users to operate electrical appliances using voice commands transmitted through wireless communication technologies. The proposed system improves convenience and accessibility compared to traditional manual switching systems. The authors emphasized that voice-based automation systems are particularly beneficial for elderly and physically challenged users who may find manual switching difficult [1].

Mozumder and Sagar proposed an intelligent home automation system using RSSI and machine learning techniques. The system used ESP32 modules to detect user location through Wi-Fi signal strength and automatically control appliances based on the user's position inside the house. The results showed high accuracy in indoor localization and efficient device control using IoT technology [2].

Iliev and Ilieva presented a smart home framework using Natural Language Processing (NLP) to enable voice-based interaction with IoT devices. The study demonstrated how voice assistants combined with IoT networks can provide natural and intuitive communication between users and smart home devices while improving system usability and accessibility [3].

Tomar *et al.* developed an IoT-based home automation system using ESP32 that allows users to remotely monitor and control appliances through a mobile application. The system provided improved scalability, real-time monitoring, and efficient control of electrical devices using internet connectivity [4].

Katumba *et al.* proposed a speech intent recognition system for IoT applications that uses machine learning algorithms to identify user voice commands and control smart devices. The research highlighted that integrating speech recognition with embedded IoT devices can significantly improve the flexibility and intelligence of automation systems [5].

Vigouroux *et al.* conducted research on speech-based interfaces for smart home systems designed for people with disabilities. Their work showed that voice interaction technologies significantly enhance accessibility and user experience in smart environments, although challenges such as background noise and speech recognition accuracy still remain [6].

Lakshmi *et al.* investigated AI-based voice-controlled smart home technology that integrates ESP32 microcontrollers with cloud platforms and voice assistants such as Google Assistant. The proposed system allows users to control multiple appliances using voice commands while monitoring device status through IoT dashboards [7].

Gladwin *et al.* developed a voice-controlled automation system using ESP32 with edge-based speech recognition. The system processes voice commands locally using lightweight machine learning models, reducing dependency on cloud services and improving system response time and privacy [8].

Akshay *et al.* proposed an ESP32-based intelligent home automation system that integrates voice control, mobile applications, and manual switches to control household appliances. The system demonstrated reliable performance and efficient energy management in smart home environments [9].

Bhaganagare *et al.* presented a voice-controlled home automation system integrated with IoT cloud platforms. The research emphasized the importance of combining cloud connectivity with voice-based control to provide scalable and flexible automation solutions for modern smart homes [10].

Overall, the literature shows that voice-controlled IoT automation systems are becoming increasingly popular due to their convenience, low cost, and ease of implementation. However, challenges such as voice recognition accuracy, system security, and reliable communication still need further improvement. These challenges motivate the development of the proposed Voice Assist ESP system.

III. GAP ANALYSIS

Although many researchers have developed voice-controlled home automation systems, several limitations still exist in current solutions. Most existing systems depend

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heavily on internet-based voice assistants and cloud processing, which require continuous internet connectivity for proper operation. This increases system complexity and may lead to delays or failure in command execution when the network is unstable.

Another limitation identified in the literature is that many systems do not provide clear real-time feedback to the user after receiving commands. Without proper feedback, users cannot easily verify whether the command has been executed successfully. Additionally, several automation systems focus only on remote control through IoT platforms but lack integration between local voice control and cloud-based monitoring, which limits system flexibility.

Therefore, there is a need for a simple, cost-effective, and efficient automation system that combines Bluetooth-based voice control, appliance control using relay modules, LCD-based command display, and IoT cloud monitoring. The proposed Voice Assist ESP system aims to address these limitations by providing reliable voice control along with real-time device status display and cloud data updates.

IV. METHODOLOGY

The block diagram of the Voice Assist ESP system represents the overall architecture and interaction between different hardware components used in the project. The main components of the system include the smartphone with voice application, HC-05 Bluetooth module, ESP32 WROOM microcontroller, 16×2 LCD display, 4-channel relay module, electrical appliances (motor/fan, LED, bulb, buzzer), and IoT cloud platform.

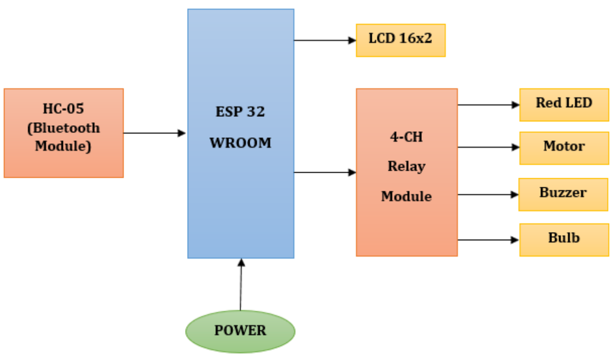

Figure 1: Block Diagram of Proposed System

In this system, the user gives voice commands through a smartphone application. The application converts the spoken voice into text commands such as *fan on/off, LED on/off, buzzer on/off, and light on/off*. These commands are transmitted wirelessly to the system using the HC-05 Bluetooth module. The Bluetooth module receives the command and sends it to the ESP32 microcontroller through serial communication.

The ESP32 WROOM microcontroller acts as the central processing unit of the system. It reads the received command, processes it, and compares it with predefined instructions stored in the program. Once the command is identified, the ESP32 sends control signals to the 4-channel relay module, which operates as an electronic switch to turn the connected appliances ON or OFF.

At the same time, the received command and the current device status are displayed on a 16×2 LCD display, providing real-time feedback to the user. Additionally, the ESP32 uses its built-in Wi-Fi connectivity to upload device status information to an IoT cloud platform, allowing remote monitoring and data logging. The entire system is powered by a regulated power supply, ensuring stable operation of all components.

V. SYSTEM IMPLEMETATION

The proposed **Voice Assist ESP system** was implemented by integrating embedded hardware modules with wireless communication and IoT technologies to achieve efficient voice-controlled appliance automation. The architecture of the system consists of an **ESP32 WROOM microcontroller**, **HC-05 Bluetooth module**, **16×2 LCD display**, **4-channel relay module**, and an **IoT cloud platform** for remote monitoring.

The **ESP32 microcontroller** serves as the central processing unit of the system due to its built-in Wi-Fi and Bluetooth support, low power consumption, and high processing capability. The **HC-05 Bluetooth module** is interfaced with the ESP32 through UART serial communication to receive voice commands transmitted from a smartphone application. The smartphone application converts speech input into text commands such as *"fan ON," "fan OFF," "LED ON," "buzzer ON,"* and *"light OFF."* These commands are transmitted wirelessly to the ESP32 through Bluetooth communication.

A **4-channel relay module** is connected to the GPIO pins of the ESP32 to control multiple electrical appliances. The relay module acts as an electrically operated switch that isolates the low-voltage control circuitry from high-voltage appliances. Based on the received command, the ESP32 activates the corresponding relay channel to switch the connected appliance ON or OFF. The appliances used for system implementation include a fan (motor), LED, buzzer, and bulb.

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To provide real-time user feedback, a **16×2 LCD display** is interfaced with the ESP32. The LCD displays the received voice command and the current status of the connected devices, thereby improving user interaction and system transparency. In addition, the ESP32 utilizes its integrated Wi-Fi capability to establish communication with an **IoT cloud platform**. Device status information is periodically uploaded to the cloud, enabling remote monitoring and data logging.

The software implementation of the system was carried out using the **Arduino IDE** with Embedded C/C++ programming. The control algorithm continuously monitors Bluetooth data received from the HC-05 module. The received command string is processed and compared with predefined command instructions. Upon successful command recognition, the ESP32 executes the corresponding control action and updates the LCD display as well as the IoT cloud database.

The implemented system was experimentally tested under different operating conditions to evaluate communication reliability, response time, and appliance control performance. The results demonstrated that the proposed system successfully achieved accurate voice command execution, efficient relay switching, real-time feedback display, and reliable IoT monitoring functionality.

VI. RESULT AND DISCUSSIONS

The proposed **Voice Assist ESP system** was successfully implemented using the ESP32 WROOM microcontroller, HC-05 Bluetooth module, 16×2 LCD display, 4-channel relay module, and IoT cloud platform. The developed prototype was tested under different operating conditions to evaluate voice command recognition, relay switching performance, LCD feedback, and IoT data transmission.

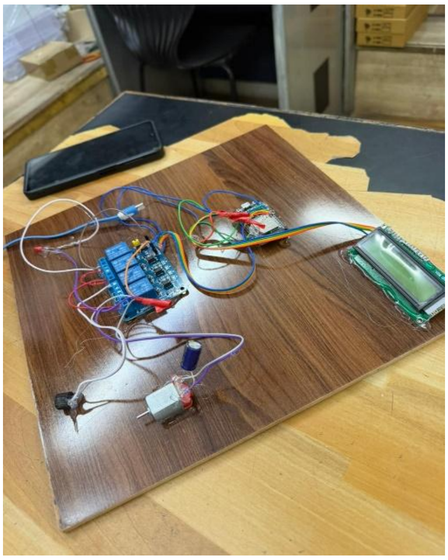

Figure 2: Hardware Setup of Proposed System

The system successfully received voice commands such as *"Fan ON," "Fan OFF," "LED ON," "LED OFF," "Buzzer ON,"* and *"Light OFF"* through the smartphone application using Bluetooth communication. The HC-05 module reliably transmitted the commands to the ESP32 microcontroller, which processed the commands and activated the corresponding relay channels. The experimental setup demonstrated stable communication and accurate appliance control with minimal response delay.

The 16×2 LCD display provided real-time feedback by displaying the received commands and appliance status. This improved user interaction and verified successful command execution. The relay module successfully controlled connected appliances including a fan, LED, buzzer, and light.

Figure 3: LCD Display Showing Appliance Status

The ESP32 also transmitted appliance status information to the IoT cloud platform through Wi-Fi connectivity. The cloud dashboard displayed real-time device status updates, demonstrating successful IoT integration and remote monitoring capability.

Table 1 summarizes the overall system performance observed during experimental testing.

Table 1: Performance Analysis of Proposed System

Parameter	Observation
Voice Command Recognition	Successful
Bluetooth Communication	Stable
Relay Switching	Accurate
LCD Feedback	Real-Time
IoT Data Upload	Successful
System Response Time	Fast
Overall System Reliability	High

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The experimental results confirm that the proposed system provides reliable voice-controlled appliance automation with efficient Bluetooth communication and IoT monitoring capability. The integration of ESP32 with Bluetooth and cloud technologies makes the system suitable for smart home and assistive automation applications.

VII. CONCLUSION

The Voice Assist ESP system was successfully designed and implemented to control electrical appliances using voice commands. The system utilizes the ESP32 microcontroller, HC-05 Bluetooth module, 4-channel relay module, and 16×2 LCD display to create a simple and efficient automation system. Voice commands given through a smartphone application are transmitted via Bluetooth to the ESP32, which processes the commands and controls the connected appliances such as a fan, LED, buzzer, and light. The LCD display provides real-time feedback by displaying the received commands and device status.

The system also integrates IoT connectivity, allowing device status information to be uploaded to a cloud platform for remote monitoring. The experimental results demonstrate that the system operates reliably and responds quickly to voice commands. The project provides a cost-effective, user-friendly, and efficient solution for smart home automation, especially beneficial for elderly and physically challenged individuals who may have difficulty operating traditional switches.

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AUTHORS BIOGRAPHY

Mufid Shaikh,
Student, Electronics and Telecommunication Engineering, AISSMS IOIT, Pune, Maharashtra, India.

Omkar Chemate,
Student, Electronics and Telecommunication Engineering, AISSMS IOIT, Pune, Maharashtra, India.

Vaishnavi Pataskar,
Student, Electronics and Telecommunication Engineering, AISSMS IOIT, Pune, Maharashtra, India.

Sachin Kokane,
Associate Professor, Electronics and Telecommunication Engineering, AISSMS IOIT, Pune, Maharashtra, India.

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