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AI-Based Voice-Controlled Assistant Using ESP32

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Abstract : *This paper presents an AI-based voice-controlled assistant using the ESP32 microcontroller. The system is designed to control electrical appliances such as lights and fans through voice commands. It uses a relay module for appliance control, a speaker for audio feedback, and an OLED display for system status. The main aim is to reduce manual effort and provide a simple, convenient, and affordable smart home automation solution.*

Keywords: Artificial Intelligence (AI), AI-Based Assessment, ESP32 Microcontroller, Embedded Systems, Automated Evaluation, Internet of Things (IoT), Wi-Fi Communication, OLED Display, Speech Recognition, Audio Processing, Voice Feedback, Real-Time Assessment, Human–Machine Interaction, Electronic Circuit Design.

I. INTRODUCTION

In today's modern world, Artificial Intelligence (AI) and automation are becoming important parts of daily life. Home automation allows users to control electrical appliances easily through voice commands. The proposed project, "AI-Based Voice-Controlled Assistant Using ESP32," is designed to control appliances such as lights and fans using voice commands.

The ESP32 microcontroller acts as the main processing unit, while a relay module controls the appliances. A speaker provides audio feedback, and an OLED display shows system information.

The system helps reduce manual effort and makes appliance operation more convenient. It also demonstrates the practical use of embedded systems and smart technology. This project provides a simple and affordable solution for smart home automation. It can be further improved by adding advanced AI features, multiple language support, and additional home appliances. The proposed system aims to make everyday activities easier, smarter, and more efficient.

Artificial Intelligence (Al) has become an important technology in the field of education, particularly in automated student assessment and evaluation. Traditional assessment methods generally require manual checking, which can be time-consuming. Recent research has explored the use of Artificial Intelligence, Natural Language Processing (NLP), and Automatic Speech Recognition (ASR) to improve the assessment process.

McKnight et al. [1] proposed a system for the automatic assessment of conversational speaking tests. Their research used a combination of speaker identification, Automatic Speech Recognition (ASR), and Al-based evaluation techniques to assess spoken responses. The study demonstrated the potential of automated systems for evaluating speaking performance.

Xiao and Park [2] investigated the use of Automatic Speech Recognition for English pronunciation assessment and learning. Their research compared machine-based pronunciation evaluation with human assessment. The findings indicated that speech recognition technology could help identify pronunciation errors and support language learning.

Cámara-Arenas et al. [3] studied the differences between Automatic Pronunciation Assessment and Automatic Speech Recognition. Their research highlighted the importance of evaluating pronunciation accurately rather than depending only on speech transcription. This work provides useful insights into speech-based assessment systems.

Gao et al. [4] presented a systematic review of automatic assessment of text-based responses in post-secondary education. Their research examined 93 studies involving automated evaluation techniques using Artificial Intelligence

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and Natural Language Processing. The study highlighted the potential of Al-based systems for evaluating students' answers and providing automated ascecement.

Based on these previous studies, the proposed AI Assessment Using ESP32 project aims to develop an embedded assessment system using an ESP32 microcontroller. The system integrates electronic components such as an OLED display and an audio output unit to provide an interactive assessment interface. It aims to demonstrate how embedded hardware can be integrated with AI-based assessment functionalities to support an automated and user-friendly evaluation process.

II. OBJECTIVES OF THE PROJECT

i. To design a voice-controlled assistant using ESP32.
ii. To control electrical appliances through voice commands.
iii. To reduce manual operation of household devices.
iv. To provide audio feedback using a speaker.
v. To develop a low-cost smart home autom. ation system.
viTo understand the practical applications of embedded systems and loT.

III. HARDWARE COMPONENTS USED

The proposed AI-Based Voice-Controlled Assistant uses various electronic components to perform voice-based operations and control electrical appliances. Each component plays an important role in the proper functioning of the system. The hardware components used in this project are described below.

1. ESP32 Microcontroller: ESP32 is the main processing unit of the system. It receives commands, processes instructions, and controls the connected devices. It also provides built-in Wi-Fi and Bluetooth connectivity.
2. Relay Module: The relay module is used to control electrical appliances such as lights and fans. It works as an electronic switch and allows the ESP32 to control high-voltage devices safely through an appropriate relay interface.
3. OLED Display: The OLED display is used to show important information such as system status and operation details. It provides a clear and easy-to-read visual output.
4. Speaker: The speaker is used to provide audio output and feedback to the user. It helps make the assistant more interactive.
5. Audio Amplifier: The audio amplifier increases the strength of the audio signal so that the speaker can produce clear sound.
6. Power Supply: The power supply provides the required electrical energy to operate the ESP32 and other electronic components.
7. connections between different components and provide proper hardware assembly.

Component	Function
ESP 32	Processes commands
Relay Module	Controls appliance
OLED Display	Shows information
Speaker	Provides audio output
Audio Amplifier	Amplifies Sound
Battery	Supplies Power

Table 1: Hardware Components And Their Functions

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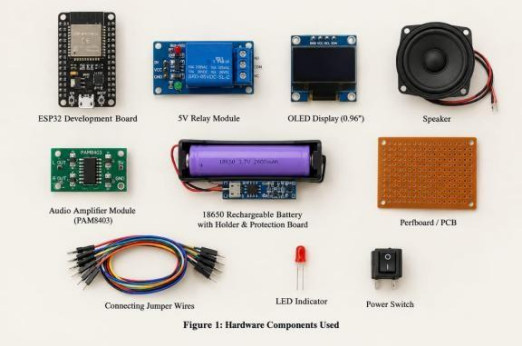


Figure1: Hardware Components Used

IV. SYSTEM ARCHITECTURE

The system architecture consists of the following stages:

i. Voice Command Input
ii. Voice Recognition and Processing
iii. ESP32 Microcontroller
iv. Output Control
v. Relay Module
vi. Electrical Appliances

Block Diagram

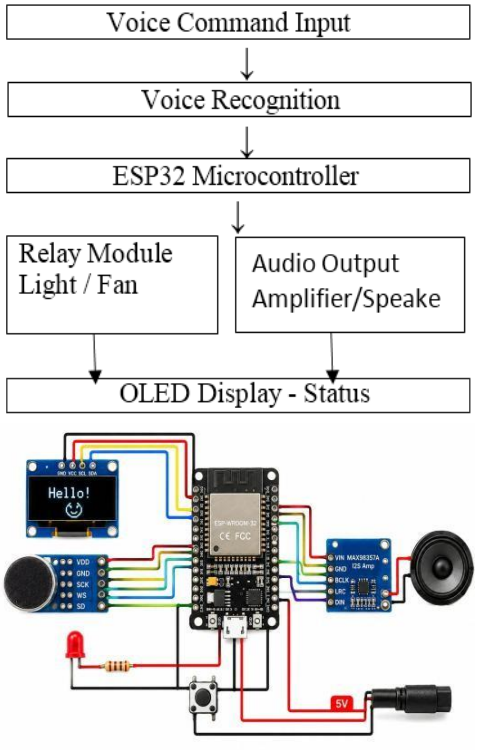


Figure 2: Circuit Diagram of AI Assessment

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The proposed AI Assessment system is designed using the ESP32 microcontroller as its main control unit. The ESP32 is responsible for controlling the connected components and communicating with the AI-based assessment system through its built-in Wi-Fi connectivity. It processes the received information and displays the assessment results on the OLED display.

The OLED display is interfaced with the ESP32 using the I2C communication protocol. The SDA pin of the OLED display is connected to GPIO 21, while the SCL pin is connected to GPIO 22 of the ESP32. The VCC and GND pins are connected to the appropriate power supply and ground connections. The OLED display provides information such as assessment results, instructions and system status.

The audio output section consists of a speaker and an audio amplifier module. The amplifier is used to increase the audio signal strength and drive the speaker to produce audible sound. The amplifier receives its input from the audio output section of the ESP32, depending on the amplifier type and interface used. This section enables the system to provide voice-based instructions and audio feedback to the user.

V. WORKING PRINCIPLE

The working principle of the proposed system is based on voice-command processing and embedded control.

i. First, the user gives a voice command.

ii. The voice recognition system identifies the command.

iii. The recognized instruction is sent to the ESP32.

iv. command according to the programmed instructions.

v. The relay module switches the connected electrical appliance ON or OFF.

vi. The speaker provides audio feedback to the user.

The OLED display shows the system status. Thus, the system provides an easy method of controlling appliances using voice commands.

VI. SOFTWARE IMPLEMENTATION

The software part of the project is responsible for processing commands and controlling the hardware.

The main software requirements include: Arduino IDE for programming the ESP32. Embedded C programming.

ESP32 board libraries. Display control libraries.

Voice recognition interface or API, depending on the implemented recognition method.

The program receives the recognized voice command, checks the instruction, and performs the corresponding operation through the ESP32 GPIO pins.

VII. HARDWARE IMPLIMANTATION AND RESULTS

The hardware prototype is developed using an ESP32 development board mounted on a perforated PCB.

The different electronic components are connected according to the circuit requirements. The relay module is used for appliance control, while the speaker and audio amplifier provide sound output.

The OLED display is used to show information about the system.

LED Indicator	Indicates System status
OLED Display	Display System information
Arduino IDE	ESP32 programming
Embedded C	Program development
ESP32 Library	Hardware control
Audio Output Software	Control speaker Output

TABLE 2: Indicators And Software Components

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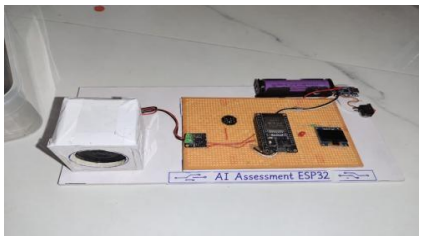


Figure 3: Proposed System Prototype

i. Voice-based appliance control.
ii. Switching lights and fans ON/OFF.
iii. Audio feedback through the speaker.
iv. Display of system status.
v. Reduced manual effort.
vi. Note: Actual performance results should be added after testing the prototype

VIII. LIMITATIONS

i. Voice recognition may be affected by background noise.
ii. 2.Internet-based recognition requires network connectivity.
iii. The system supports only programmed commands.
iv. Power supply limitations may affect continuous operation.
v. Recognition accuracy depends on the voice input and software.

IX. FUTURE SCOPE

The project can be improved in several ways:
i. Integration with advanced Al models.
ii. Support for multiple languages.
iii. Addition of more household appliances.
iv. Development of a mobile application.
v. Offline voice recognition.
vi. Integration with smart home security systems
vii. Improved natural language processing.

X. CONCLUSION

The proposed Al-Based Voice-Controlled Assistant using ESP32 demonstrates the application of embedded systems, automation, and artificial intelligence concepts. The system provides a convenient method of controlling electrical appliances through voice commands.

By integrating an ESP32 microcontroller, relay module, speaker, audio amplifier, and display, the project provides a foundation for developing smart home automation systems. The proposed design is affordable, compact, and can be further improved with advanced Al technologies.

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