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Offline Speech and Gesture-Controlled Smart System for Accessibility and Safety

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ABSTRACT

5

According to a survey census done by the World Health Organization (WHO) An estimated 1.3 billion people worldwide—approximately 16% of the global population—experience significant disability. Despite these substantial discussions surrounding the safety and support of individuals with disabilities often remain unresolved. To address this critical issue, we propose the development of a system that empowers disabled individuals to control electrical devices without the need for internet connectivity. This system will integrate speech and gesture recognition technologies, enabling users to operate appliances through natural interactions, thereby enhancing accessibility and independence. Additionally, the system will feature an emergency safety mechanism, allowing users to alert caregivers, family members, or neighbors in times of distress. By combining intuitive control interfaces with robust safety features, this project proposes a comprehensive and an efficient solution that aims to improve the quality of life for people with disabilities.

6

Key Words: Sensor, Arduino, IoT, Safety, Equality, Privacy.

1. INTRODUCTION

11

In a world where technology is advancing rapidly, accessibility and inclusivity remain crucial aspects of innovation. Individuals with disabilities, often encounter difficulties in performing everyday tasks such as controlling home appliances. Traditional systems rely heavily on manual switches or mobile applications, which can be inaccessible or inconvenient for such users. Additionally, many smart home automation solutions depend on internet connectivity, limiting their reliability in regions with poor network coverage.

To address these challenges, we propose an Offline Speech and Gesture based Smart Home Automation System designed specifically for individuals with disabilities. This system leverages speech and gesture recognition technologies to enable seamless and natural interaction with home appliances, eliminating the need for physical switches or internet access. By integrating an emergency alert mechanism, the system also enhances user safety, providing a holistic solution for independent living.

By prioritizing accessibility, reliability, and ease of use, this system bridges the gap between technology and inclusivity. It contributes to a future where smart home automation is accessible to everyone, regardless of their physical abilities.

2. RELATED WORKS

M. Periša et al, proposed a paper [1] that introduces an innovative approach to assistive technologies for individuals with disabilities. It emphasizes the importance of collecting and storing data in well-structured databases to generate predictive user information based on user profiles. The paper highlights the role of AI and ML in improving accessibility and autonomy by providing predictive insights into user preferences, habits, and potential incidents while also discussing a conceptual mathematical model for generating user-specific information, virtual assistants to manage home devices through speech.

Y. B. Anwaraly et al, developed a system [2] that integrates various hardware components, including a gesture sensor, Bluetooth module, Arduino, LCD display, and a 4-channel relay module to manage devices such as fans, lights, etc. Voice commands and hand gestures are processed via Arduino, activating or deactivating appliances through relay modules. The Bluetooth module allows remote operation via smartphones, enhancing convenience and accessibility. A LCD display provides real-time feedback and status updates, improving user experience with clear and concise information.

N. Chumuang et al, designed an assistance system for aged people [3] using voice commands by implementing speech recognition technology. This system is designed in a way it is useful for elderly individuals and also reduces their labour costs associated with hiring trustworthy care-takers. It also implements the principles of the Internet of Things (IoT) to control various household electrical devices through voice commands. Through the Natural Language Processing (NLP), the system interprets the voice commands, allowing users to control lights, applications, make phone calls etc.

R. Manjesh et al, published a paper [4] explores the development and potential of hand and face gesture recognition systems, which use machine learning (ML) and other computer-vision techniques for effective communication and interaction for individuals with physical disabilities. The paper stresses upon the importance of user-centered design and accessibility standards for real-world deployment, emphasizing the significant impact of gesture recognition technology in improving the quality of living.

P. R. Bagane et al, developed a system [5] enhances mobility, safety, and independence by utilizing advanced sensors like ultrasonic and infrared to detect obstacles and hazards in real-time. It provides timely audio and haptic feedback through Bluetooth-enabled earpieces or wearable devices, ensuring users can navigate safely without excessive information. The system also incorporates machine learning techniques to differentiate between stationary and moving objects, and its GPS and voice-command features assist with navigation.

3. PROPOSED WORK

This paper presents a system that utilizes voice commands and gestures as input through voice recognition and gesture sensors to enable disabled individuals to control electrical devices seamlessly. The proposed system aims to enhance accessibility and independence by providing an intuitive interface for device control. Additionally, the system incorporates a safety alert mechanism designed to offer immediate assistance when necessary, ensuring the well-being and security of users in critical situations.

3.1 The Architecture of the project

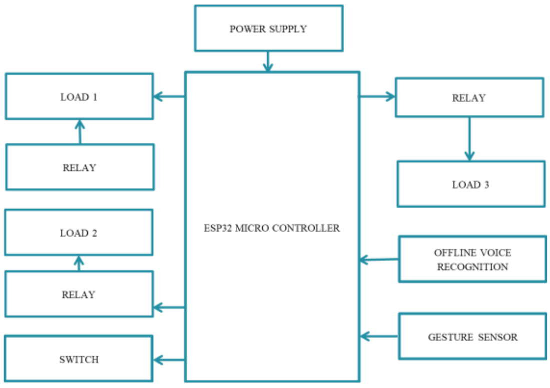

Fig.1 Architecture of the Proposed Work

HARDWARE REQUIREMENTS

3.1.1 VOICE RECOGNITION SENSOR

Voice recognition, a sophisticated technology that analyzes and converts speech commands into editable texts or other forms of input. This speech recognition sensor works in offline mode and is built on a customized microprocessor that allows voice recognition without an internet connection. Its twin microphone design improves noise resistance high accuracy and dependability even in noisy conditions.

Fig.2 Voice Recognition Module

3.1.2 GESTURE SENSOR

A gesture sensor detects and converts hand gestures into commands for a variety of applications, including smart home automation, robotics, and gamingThe operating idea is based on infrared (IR) technology, with an IR LED generating light and four directional photodiodes sensing reflected IR light from hand movements in four directions (UP, DOWN, LEFT, and RIGHT). The sensor uses an algorithm to determine the gesture direction, then transfers the data to a microcontroller via I2C, where it can interpret and execute actions based on the identified gestures.

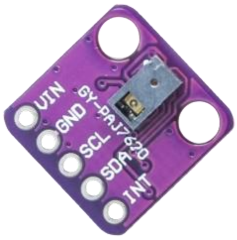

Fig.3 Gesture Sensor

3.1.3 ESP32 Microcontroller

Espressif Systems developed the ESP32, a powerful and adaptable SoC microcontroller for IoT, embedded, and real-time applications. With up to 34 programmable GPIOs, motor and LED PWM, the ESP32 is an excellent solution for IoT developers and hobbyists seeking great performance, connectivity, low battery consumption, and better security.

Fig.4 ESP32 Microcontroller

3.1.4 Power Supply Adapter

An AC adapter, sometimes known as a "recharger," transforms high-voltage AC from a household power supply (220-230VAC) to low-voltage DC (12VDC) suited for powering or charging consumer electronics, assuring safe operation of devices with varying power requirements. They also allow smooth data exchange between front-office and back-office systems and provide access to consistent, reliable information.

3.1.5 Relay Board

A relay board is an electromechanical switch that can be controlled both electrically and physically. A relay is made up of an electromagnet and a set of contacts, with the electromagnet acting as a switch. A four-relay board configuration consists of a driver, a power supply circuit, and an isolation circuit, with which the relay is integrated into an arrangement. With a 12VDC input voltage, the relay board enables quick switching and allows for tasks such as motor forward and reverse control. Its uses include AC and DC load switching and motor control, which is an integral component in many industrial and electronic systems.

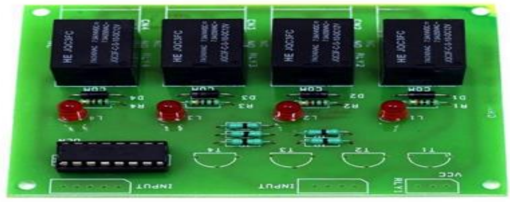

Fig.5 Relay Board

SOFTWARE REQUIREMENTS

3.1.8 Arduino IDE

Arduino- Integrated Development Environment (IDE) is a cross-platform application for Windows, macOS, Linux that is built using the functions of C and also C++. This IDE is used not only to write and upload programs to Arduino-compatible boards, and also other vendor development boards.

Fig.6 Arduino IDE

3.1.9 Embedded C

Embedded C is a C programming language extension designed specifically for the embedded systems, connecting high-level programming and low-level hardware control. It is widely used in automotive, IoT, and signal processing and provides high-level abstraction for low-level processes, making it an effective tool for developing embedded applications.

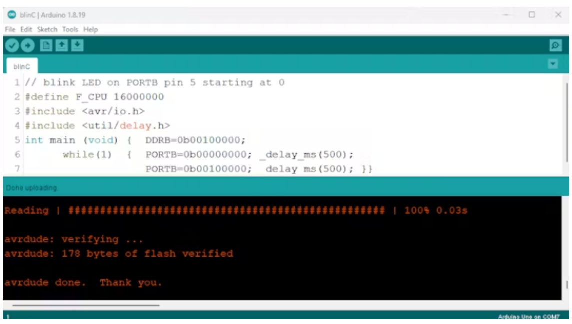

Fig.7 Embedded C

3.2 Working of the Proposed System

The offline speech and gesture-controlled system is designed to assist people with any sort of disability in operating required electrical items without physical involvement. The system runs entirely offline, removing the need for an internet connection, hence increasing privacy, reaction time, and reliability by processing commands locally. The core of this system is the ESP32 microcontroller, which incorporates an offline voice recognition module that can store and match predefined speech commands such "turn on," "turn off," "fan," and "light." During the initial setup, consumers record their voice for particular requests, which the system recognises and performs promptly.

The system also contains a PAJ7620 gesture sensor for spoken commands, providing an alternate control mechanism based on programmed hand gestures. This allows users to control appliances with simple hand gestures like swiping left to turn on the light, right to turn it off, up to start the fan, and down to deactivate it. This dual-mode control method increases accessibility by allowing users to switch between speech and gesture-based interactions based on their preferences or convenience. The ESP-32 micro-controller acts like the central processing unit(CPU), communicating with the speech recognition module, gesture sensor, and the relay modules to operate electrical appliances. The relay functions as switching devices, enabling the system to turn lights and fans on and off when needed.

Its offline nature protects user privacy because no data is sent to other servers. This makes the system appropriate for residential settings, aged care institutions, and rural places with minimal internet connectivity. The system is also expandable, allowing users to extend control to many appliances by including more relay modules.

3.3 Experimental Results

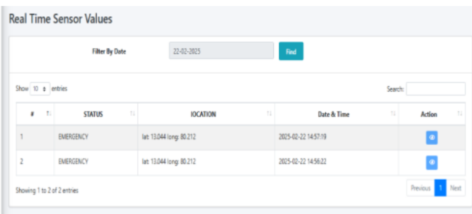

Fig.8 Alert Message Database

Fig.8 represents the application output. When the user gives a specific command, after the execution of the command, the action is recorded on the app.

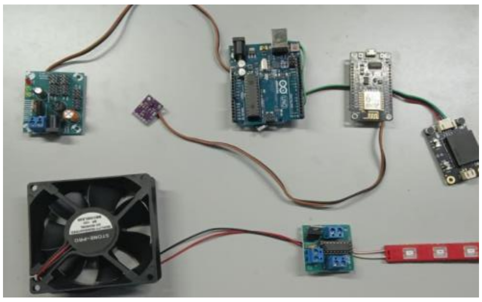

Fig.9 Hardware Setup

Fig. 9 demonstrates the overall setup of the electrical components the proposed system.

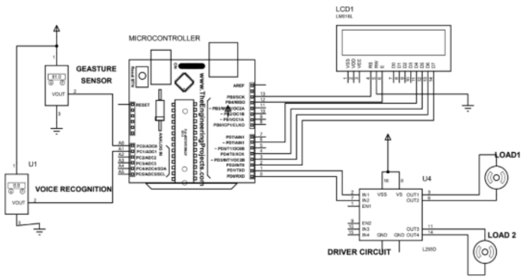

Fig.10 Load Control

Fig. 10 uses gesture and voice recognition to operate electrical loads via a microcontroller and motor driver circuit.

4. CONCLUSION

To sum up, this project effectively illustrates a complete offline enabled-home automation system designed to improve the disabled people’s standard of living. The technology ensures accessibility and convenience without depending on internet connectivity by combining voice recognition and gesture-based controls to provide an easy-to-use interface for controlling household appliances. The system's usefulness is further enhanced by the addition of an emergency safety mechanism, which gives users more security and freedom.

5. FUTURE SCOPE

To achieve better results and advance the technological capabilities of our project, we plan to incorporate key features and functionalities inspired by Amazon Alexa and Google Assistant. This integration will enhance

10

overall performance, improve functionality, and significantly increase ease of use, particularly for individuals with disabilities. By leveraging voice-controlled technology, intelligent automation, and personalized assistance, our project will provide a more accessible and user-friendly experience, empowering disabled users with greater independence and convenience.

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