Voice Assistance for Visually Impaired Persons Using AI and IOT

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Abstract—*The World Health Organization (WHO) states that visually impaired persons constitute a substantial variety of people global who are unable to handle day to day activities, train and work. Still more than eighty% of human notion is through imaginative and prescient, and visually impaired people face points of access to digital statistics. To resolve this, we current a speech-based totally assistive machine that uses Automatic Speech Recognition (ASR), Text-to-Speech (TTS) synthesis, and AI-IoT integration to make for an easy interaction through herbal talk. There is a microphone (MIC) that collects voice input, that is processed to textual content, and transmitted to a ChatGPT API server. Thus, the usage of a voice processor module converts the response back into speech, which is fed through a speaker in order to perform auditory comments. Furthermore, the grasp ChatGPT processor commands are processed by a slave microcontroller that displays real-time manipulation of commands, path, and feedback status. Initial prototype checking proves promising results and shows that such a system could be a useful assistive generation for visually impaired users by giving them a hand in improved access and independence.*

Keywords—*Assistive system, ASR, TTS, AI-IoT, ChatGPT, voice interaction, microcontroller, accessibility*

I. Introduction

With the fast change in digital technology, interaction between humans and computers has changed quickly, and voice-controlled systems have become popular as they are. In this paper, the design and implementation of a voice aided system based on the ESP32 microcontroller are concerned. The system uses the NLP techniques and voice recognition capabilities to improve the efficiency of interactions with smart device through maintaining the privacy and security of the user. Nowadays, voice-controlled assistants are a priority in daily life, providing ease when need to set a reminder, control home automation systems and look up information over the internet. These systems are based on speech recognition and the command processing for the effortless communication between the connected devices and users. This research provides contribution in this growing field by introducing a smart device management using a personal voice assistant based on ESP32 microcontroller, which is easy to use and affordable. We choose to use ESP32 microcontroller as the heart of this system because it is versatile, low power consumption and has integrated Wi-Fi as well as Bluetooth components. These are the ideal features for an Internet of Things (IoT) application which requires real-time connectivity and remote-control functionality. Utilizing these capabilities allows the proposed voice assistant to provide a reliable and responsive user experience while solving the most important data privacy and security issues. One of the core functionalities of this system is to interpret and process voice commands in an accurate manner so we can let the users perform various tasks using sophisticated smart home appliances, web-based information or even to set notifications. In addition, the design keeps in mind a seamless integration with many smart devices so as to control the interconnected ecosystem by leaps and bounds within a household or workplace. Thus, encryption protocols and authentication mechanisms are included within the system in order to enhance data security and user privacy. Such measures protect sensitive information from unauthorized access and guarantee a solid and trustworthy contact between the user and device. Furthermore, data handling techniques are applied to provide efficient treatment of data in order to maximize system performance while securing minimum delay in response time. This system is designed in which it has the interface which is very easy to use for users that differ in terms of technical skills in the use of it. Superior voice recognition software they use employs also to increase correctness of the commands and thus decrease error rates and increase an overall quality of the response. Also, the ESP32 microcontroller can operate energy efficiently and keep the system viable for continual use with no excessive power consumption. This voice assistant is one the most adaptable one that was developed which allows it to be applied to home automation, industrial applications or healthcare systems. It is scalable for future extensions including integration of cloud-based service for enhancing its functionalities.

II. RELATED WORK

An Internet of Things (IoT) voice assistant by R. P. et al. would use a Raspberry Pi and Natural Language Processing (NLP) to let smart voice assisters to handle multiple languages offline [1]. Our approach is developed based on AI and IoT for real time object identification and interactive voice help, whereas their system focuses on the language processing and automation. A. Patil et al. also suggested a low cost Internet of Things (IoT) based smart shoe with ESP32, gyroscopic, infrared and ultrasonic sensors for obstacle detection and support navigation for visually challenged people [2]. Through the use of AI-driven item detection and real time voice guiding we enable more interactive and encompassing help system than the one they rely on in the form of vibration and audio warning through a smartphone app. J. Hemavathy et al. suggested an AI based voice assisted objects recognition system using the combination of object detection, OCR and K nearest neighbour (KNN) machine learning to detect objects real time by using smartphones for visually challenged people [3]. As compared to their method, our system uses IoT integration and real time object detection driven by AI to enhance the accessibility to the solution and provide a more interactive and autonomous navigation. S. C. Jakka et al. [4] have built a blind aid system using TensorFlow with SSD method of object detection and distance estimation. Whereas we have a more complete assistive solution by combining IoT and AI driven, real time voice access for navigation and interactive directions, they venture into item and localization recognition with voice. According to Dheeraj et al., an assistive vision system that uses Alexa and combined the computer vision, object identification and artificial intelligence technology is suggested in order to help blind or visually handicapped people. As a result, our method boosts accessibility with AI and IoT for real time item identification and interactive voice help while theirs rests in the latter. Furthermore, our system offers the benefit of free independence by making it possible to get rid of the need of cloud-based voice assistants. Internet of Things based processing is an economical and effective substitute offered for the visually challenged people. To develop a wearable smart glass that includes computer vision and Internet of Things, Bhuiyan et al. developed this smart glass for the use of one that suffers from visual disabilities and real time object and facial recognition for concrete aural feedback [6]. Thus, our method enables a more flexible and cheaper solution without needing dedicated wearables, compared with their system, which requires glasses. To provide assistance to elderly people of controlling their household devices with voice commands, Chumung et al. has created a voice activated system with speech recognition, IoT and NLP [7]. Our strategy includes real time object detection with AI and IoT for visually impaired people and improves convenience for older users with their system. Manikandan et al developed a smart voice assistance system (Manikandan et al. 2017) for visual impairment where speech and speech alarm were delivered with the help of Arduino and its sensors to identify impediments [8]. By integrating AI and IoT for real time item recognition and interactive voice assistant, our method improves accessibility while their framework focuses on barrier detection and does not offer such a flexibility and multi-function assistive solution. Chitra et al. [9], presented a voice navigation guidance device with obstacle identification and the use of navigation using LiDAR sensors, vibrotactile units, and convolutional neural networks (CNNs). As an interactive voice assistive and real time object detection solution that is more accessible and adaptable than the wearable, sensor driven device of theirs, our method uses AI and IoT. The Annamaneni et al have proposed an AI based voice assistance system. It takes picture using an external camera and then uses machine learning model to label those objects. After converting the input to speech, the output is then used by a Text-to-Speech (TTS) API [10]. We enhance the accessibility by using the more responsive and autonomous navigation solution based on real time IoT identification of objects coupled with interactive voice guidance whereas their technology is based on voice enabled image processing. Rao and Singh repositioned the latter [11] by integrating such sensors, computer vision, the Internet of Things into a shoe based assistive device to provide for a smart navigation system for those who have visual impairments to allow obstacle identification and navigation with haptic feedback. With AI powered real time item detection, and voice guided cue, we offer more flexibility and more engaging solution than is possible with their wearable sensor based support system. From the prior paper by Subha et al. [12], they used an object tracking, ultrasonic sensor system with AI boards to provide real time auditory feedback to people with visual impairments. While the direct intervention of their system is based on video based object detection system, our method utilizes a more flexible and responsive assistive solution by combining AI and IoT to perform them in a real time object recognition and interactive voice guiding. In a long term health surveillance system, they developed a healthcare system for internet ware of things based to measure sleep apnea and shallow breathing by using wearable sensors [13]. Our AI and IoT driven method is to perform real time object detection along with voice help to the visually impaired people so they work a lot independently and do their navigation better, while their system is a medical diagnosis and patient monitoring system. In order to identify forced contact and provide warnings for the safety of female children, Kavitha and Swaminathan [14] created a wearable nanocomposite sensor in a hairclip. We do this by using AI and IoT to identify real time objects and provide voice help to people navigating through their journeys with visual impairments whereas they focus on personal security. To investigate the combination of robotic rehabilitation and machine learning to improve wrist therapy for those with hemiparesis, Gangadhar et al. [15] have done so. Our architecture combines AI and IoT to retrieve real time objects and voice help for visually impaired people independence and better navigation at cost of healthcare and rehabilitation of the system.

III. PROPOSED SYSTEM

At the same time, the system is devised to develop a voice aid device specifically intended to fulfill the requirements of the visually impaired in enhancing how they interact with their environment. Essential hardware elements include a speaker, microphone, push buttons, an HT7333 rated of 24 70V (up to 3A) voltage regulator, a slide switch, a battery and a TP4056 charging module. With every component, a wise choice is made for effectiveness in performance and ease of utilization. The system is activated via a slide switch which then turns the device on whilst starting the interaction. The microphone recordings the user's voice, and then processes to extract the voice input commands. Being a built-in Wi-Fi and Bluetooth enabled core processing unit from ESP32-WROOM-32D microcontroller, it easily communicates with external data sources. When the voice command is over, the system produces some kind of response and then changes it to phoneme and plays in the speaker. Thus, visually impaired people have a clear and audible feedback, so they can perform it hands-free. Adding a text to speech module improves accessibility as all responses are readily conveyed. The device is further enhanced with three red LEDs and push buttons. In addition to that, the push buttons provide users with ability to start or stop interactions, and vary the sound levels or select different operating regimes. Thus, the red LEDs on the device give a visual feedback on the device status, i.e. they display a power activation, active communication or even charging progress. The HT7333 voltage regulator supplies a 3.3V power output, so as to maintain the steady operation state of the power components under voltage fluctuations. A rechargeable battery and a TP4056 charging module being included in the power management system to make it long term usable and portable. The TP4056 includes neat battery charging, which won't discontinue the use of your sander. An integrated advanced hardware component plus an efficient processing mechanism is used to facilitate an integrated and responsive as well as user friendly voice assistance system. On top of that, the design isn't only easy for us to use, but also makes everyday usage of this easier for visually impaired individuals. Efficiency, functionalities and additional smart features for better user experience is what future developments may expend for to become better. Voice assisted systems allow for easy natural interface of people to machines through speech recognition and processing. The following block diagrams show the archetecture of voice input and output presents in voice input and output processing for real time operation. The voice input is captured and processed by the transmitter section. The user's speech is collected by the microphone, the ESP32 microcontroller processes the collected speech. This means that the spoken commands are stored, the relevant data is wirelessly transmitted, and is further processed.

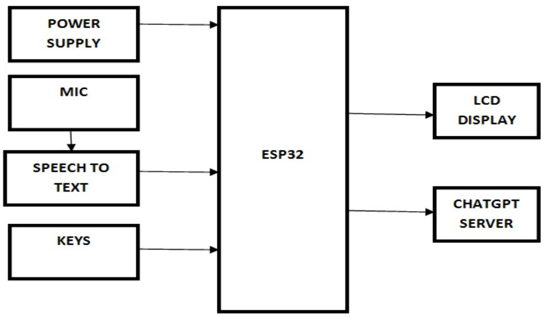

Fig 1. Block Diagram of Transmitter Section

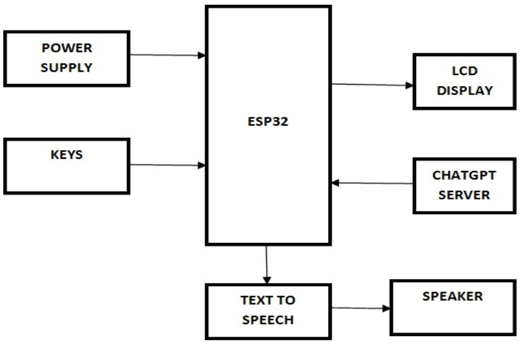

Fig 2. Block Diagram of Receiver Section

ESP32 microcontroller will interface with various input devices like a microphone, speech to text module and keyboard in the Transmitter Section shown in Fig. 1. The data is then processed, and the result is transferred to the ChatGPT server for further processing and displayed on an LCD. In Fig. 2, it is shown that the Receiver Section is the ESP32, interpreting keystroke input, translating text to speech, displays the result on an LCD, and plays it over a speaker.

A. NODEMCU

The ESP8266EX is an ESP8266 standalone Wi-Fi networking module that comes with on board flash memory outside of the chip itself and that will run from the external flash memory. This is meant to be used in an efficient way that is integrated into wireless internet, and can connect to a lot of microcontroller systems using SPI, SDIO, I2C, or UART according to the chosen communication protocol. In fact, this module functions as a compact Wi-Fi adapter with no other hardware needed for a seamless and easy connectivity.

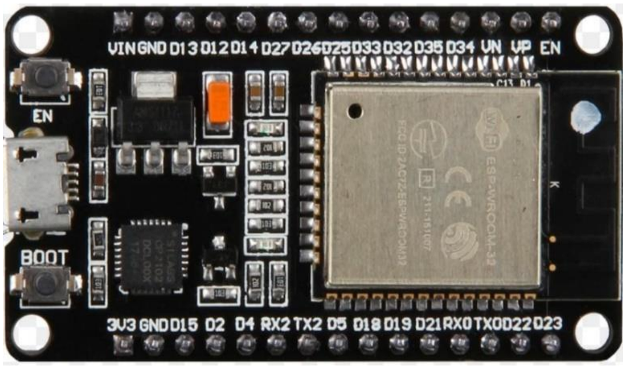

Fig 3. ESP8266EX Microcontroller Module

Fig. 3 demonstrates the ESP8266EX microcontroller module, enabling Wi-Fi connectivity and efficient processing for IoT-based voice assistance. As it's really small, it's a big advantage for any application in which it is needed to save space. The module comes equipped with an advanced 32-bit Tensilica L106 Diamond series CPU, powers which are high. Other components, including on the chip SRAM to increase processing efficiency, are also included. These features work on top of each other allowing for reliable Wi-Fi communication minimized power consumption and minimized processing capability.

B. INMP441

The omnidirectional MEMS microphone with low power and high performance, base port, and digital output is INMP441. Further, it embeds essential components including a MEMS sensor, signal conditioning circuitry, an ADC, a power management circuit, and anti-aliasing filters. A 24 bit I^2S interface microphone is the one you'll find and it works well with current digital systems. As it does not need an internal sound code, it is to be coupled with a microcontroller or digital signal processor (DSP) which can directly use in the Ands interface, therefore simplifying the system design and minimum delay. The primary benefit of the INMP441 lies in its high signal to noise ratio (SNR) that provides high clarity and accuracy in applications where high level of accuracy in sound reproduction is required. Therefore, it has a wide frequency response thus suitable for recording natural and detailed audio signals. Applications like voice recognition, audio recording and many other real time communication systems utilize the microphone very well. With its small surface mount package of 4.72 × 3.76 × 1 mm it provides the space efficient integration in today's electronic devices. The INMP441 is ideal for integration in wearable tech and IoT, portable products, smart assistants and it consumes very less power with high-performance capabilities. Fig 4 is the INMP441 MEMS microphone module, an example of microphone module which works through capturing voice input at minimal noise, and converting the voice input into digital signals for processing.

Fig 4. INMP441 MEMS Microphone Module

C. *Text-to-Speech Speaker*

The MAX98357A/MAX98357B is a high-quality, power efficient and easy to use Class D audio amplifier for Pulse Code Modulation (PCM) input. This combination of the Class AB amplifier's better audio performance with the Class D's power savings is ideal for low power applications. This amplifier is one of the mains features that it can be used to automatically identify the audio formats and it does it with up to 35 PCM and TDM timings without an I²C programming. In addition, it is able to operate without the associated need for external MCLK signal in PCM communication. By simply powering up LRCLK, BCLK and digital audio inputs, users can obtain audio output, therefore reducing system complexity and making it suitable for various embedded and IoT applications. Fig. 5 shows the Text to Speech (TTS) Speaker Module which converts digital text to a humanlike speech for end user interaction.

Fig 5. Text-to-Speech (TTS) Speaker Module

D. *Speech-to-Text Module*

In voice assisted systems, Speech to Text (STT) part plays a very important role of converting spoken language to virtual textual content. Applications designed for visually impaired can use this module as it is integral to enable such applications to interact with the system in a natural manner through speech.

1) Voice Capture and Processing

A high performance INMP441 MEMS microphone is employed by the STT module to capture a voice input with little noise interference. The analog sound waves are converted into digital signals by microphone and sent to the microcontroller for processing.

2) Speech Recognition Algorithm

The processed voice data is then fed to Artificial Intelligence (AI) based Speech Recognition algorithms which interpret and transcribe spoken commands with a very high level of accuracy. Naturally Language Processing (NLP) techniques are used in these algorithms to improve the contextual understanding and a precise command execution. Fig. 6 shows speech processing and output system which uses AI based speech recognition for voice command and audio response generation.

Fig 6. Speech Processing and Output System

3) Integration with the Microcontroller

Central processing unit (CPU), ESP32-WROOM-32D microcontroller helps to facilitate real time communication between Speech to Text (STT) module and other system components. The STT module takes in the speech input, converts it into text, and the resulted text goes through a ESP32 module that decides on which action to do. The transcribed text can be displayed on an LCD module to the user or you can execute commands such as activating peripherals, generate a voice response using the Text to Speech (TTS) module, or talking to cloud-based AI services for fancier processing. The ESP32 runs on a regulated 5V supply of 12V, 1A adapter and allows for reliable and flawless system operation with built in Wi-Fi in order to have seamless data exchange.

E. *LCD Display*

The Liquid Crystal Display (LCD) module is a visual output interface for receiving system responses, status update and transcribed speech input in the real time. Complementing voice output with textual feedback, this module makes the app more accessible for users.

1) Text Based Output for Improved Usability

Real-time interaction is visible through the LCD display, which allows the user and the system operator to see what is happening. This is especially useful when validating voice commands in a secondary manner.

2) Low Power Consumption and High Readability

The LCD module is made for energy conscious operation, requiring little power and making it a good choice for battery powered IoT applications. A monochrome screen means readability and high contrast even in changing lighting environments.

3) Seamless Integration with the Microcontroller

Then the process of processed data is transmitted to the LCD screen where it is presented clearly and organized in a structured way. By integrating the voice assistant into this system, reliability is improved, thereby, ensuring that the voice assistant can have a smooth communication with its users.

Fig 7. 16x2 LCD Display Module

Fig. 7 the 16x2 LCD Display Module, which is used for the real time text output of the voice assistance systems to give it a rough edge for better usability and accessibility.

F. Key Hardware Components in the System

Various basic hardware modules to facilitate an efficient running of the system including user input and communication are based on this system. The Speaker Module is a crucial part of producing audible sound output from digital signals, which support the TTS capability. An Audio Amplifier Circuit has been included for the purpose of transmitting quality sound and getting audio clarity and volume enhancement. Mostly they use Pull Buttons to activate recording or to stop procedures, or to start again system easily, for the purpose of user interface. A Power Regulation Circuit is utilized for reliable power supply which blocks voltage fluctuations as well as protects sensitive elements from damage. An Antenna Module ensures wireless communication by providing Wi-Fi connectivity meant for both cloud processing or local processing. Moreover, LEDs indicate system status instantaneously, serving as convenient feedback for the vital information such as the availability of power, the status of recording and processing updates. Finally, the Power Input and Distribution Unit helps in ensuring that the system receives the needed energy supply from the components as there are both external and USB power sources. Taking together these major hardware components, the system should perform well, only with effective functionality in speech processing and real time communication.

IV. Result and Discussion

Human – computer interaction becomes easier with the combined use of speech to text (STT) and text to speech (TTS) technologies that helps in voice to voice conversation. The mechanism records the mouthed message on a microphone that has a high sensitivity, and translates the text to digital with the help of a microcontroller. The text displayed on this LCD module is transcribed real time to the user. Next, the processed text data is passed on to a TTS engine and then the synthesized speech signal is played on a speaker. The LCD screen, on the other hand, makes the system more usable by displaying the system status and the message of speech recognition and finally the confirmation message. Due to the combination between real time speech recognition, visual feedback and audio output, this system is particularly appealing in the assistive applications, smart automation, and hands free control systems. Overall, the design focuses on accuracy, low latency and user interaction, and it can be used as a possible solution for improving accessibility and user interaction in many fields.

Fig 8. Speech-to-Text and Text-to-Speech Integration System

Fig. 8 introduces the integration of Speech to Text (STT) and Text to Speech (TTS) systems for smooth voice-based communication and interaction. A voice input functionality has been incorporated in this project to enhance accessibility through spoken commands without any hindrance. There, the system utilizes speech recognition technology, that records voice input, transfers it to text, analyzes the information and provides meaningful responses. With such a thing, traditional text-based input is getting obsolete; a more intuitive and informal communication medium. The system also represents real time voice processing of various speech patterns and accents along with accurate response in terms of context. Mostly meant for the benefit of the visually impaired users, this technology acts as a digital guide, where the users can give their inputs through speech and receive the desired feedback audibly. Voice input and output features allow for a more practical and reliable daily assistance since including them in the system enhances usability. In addition, the system utilizes advanced voice commands noise filtering techniques in order to reduce background interference thereby preventing misinterpretation of voice commands even in noisy environments. It allows the user to have a smooth and uninterrupted interaction. The system also ingests the speech patterns of the user over time and can adapt and become more accurate and responsive as the user speaks with the system in the future. Result analysis of the result of the ChatGPT Voice Assistant is presented in Table 1 with accuracy, response time, power consumption, and overall system efficiency as presented in the table.

TABLE I. RESULT ANALYSIS TABLE FOR CHATGPT VOICE ASSISTANT USING ESP32

Criteria	Component/ Aspect	Measurement Method	Actual Result
Voice Recognition Accuracy	Microphone + Speech-to-Text (STT)	Accuracy of voice-to-text conversion	95% accurate transcription
Response Time	ChatGPT API	Time taken for API request and response	1.8 seconds
Voice Response Quality	Text-to-Speech (TTS)	Clarity, naturalness of synthesized speech	Somewhat robotic but intelligible
Wi-Fi Connectivity	ESP32 Wi-Fi Module	Connection stability and speed	Occasional dropout
Power Consumption	ESP32 + Peripherals	Current draw under load	180mA
System Reliability	Overall System (Voice, API, TTS)	Number of successful/failed interactions	98% successful interactions
Error Handling	System Resilience	Number of errors or crashes	1 crash every 50 interactions
User Experience	Entire System	User feedback (ease of use, responsiveness)	User satisfaction 90%
Cost Efficiency	Hardware and Software	Total cost of system components	$35 total setup cost

Promoting such technology development, the project implements this feature to help visually impaired people become more independent. In this innovation of inclusivity being fostered, users are able to get comfortable with taking advantage of information and assistance easily over a simple voice-based interaction system.

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