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Article

An Integrated AI Virtual Assistant Platform Featuring Smart Display and Automation Capabilities

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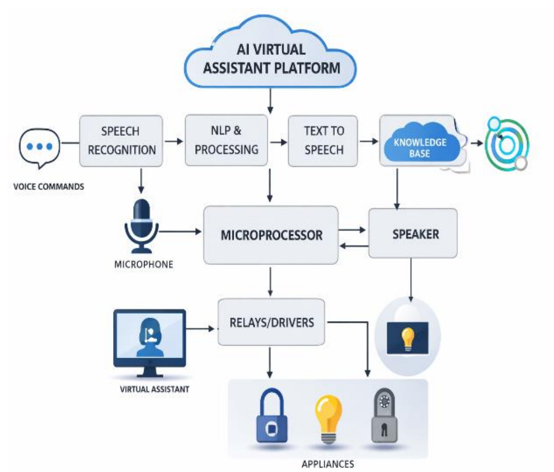
ABSTRACT

The arrival of Artificial Intelligence (AI) and the Internet of Things (IoT) has led to the development of programming-based environments for domestic and commercial applications of automation. This work is distributed into three sections: virtual assistant (VA), domestic robotics, and advanced user interface demonstration. A dissimilar public library is utilised for a virtual assistant and information to identify them, concluding the communication recognition procedure and then replying by viewing all the effects on the display screen. Domestic automation includes monitoring and changing applications. IoT-based methods were used to control the brightness of the bulb, and an IoT-based technique was used to control the speed of the DC fan. Finally, the output was displayed using a Graphical User Interface (GUI) constructed using the QT-designer tool and PyQT library. The primary value of this work is the ability to combine an AI-based virtual assistant, home automation, and a real-time graphical user interface into easy use system. Operator instructions are examined to deliver optimum solutions. The proposed scheme has better functional coverage, real-time visualisation, and better user interaction in comparison with the existing benchmark systems, which mostly concentrate on voice-based helpers and distributed IoT control systems. This scheme is recommended for use as an intellectual virtual assistant, which understands human speech and answers through created voices. This work is new because it is the first work where an AI virtual assistant, IoT based automatization, and real-time smart display are combined to make the interaction and constant situational awareness happen within one platform.



Keywords: Data Centers; Deep Learning; Green Grid Computing; Load Forecasting; Long Short-Term Memory (LSTM); Sustainable Energy Management; Recurrent Neural Networks (RNN)

1. Introduction

The rapid development of cloud technology has enabled universal worldwide connectivity. Wireless embedded equipment authorised by software communication, Artificial Intelligence (AI), and the Internet of Things (IoT) are attractive living values and convert regular actions through households, workshops, and educational surroundings. This digitalisation wave has encouraged the extensive acceptance of Virtual Assistants (VA) that modernise responsibilities such as data recovery, program organisation, and multimedia entrance, gradually mixing with physical surroundings and concluding home-based robotics schemes. This work offers a joint outline that unites three serious areas:

- **Voice-Activated Intelligence:** Speech acknowledgement collections and Google's Text-to-Speech (TTS) can be used for bidirectional speech communication, transforming consumer instructions into executable responsibilities.
- **Adaptive Appliance Control:** Ranging outside binary transferring to comprise the physical parameter of equipment. For example, PWM-driven fan speed modulation and IoT-based bulb control.
- **Context-Aware Visualisation:** A PyQt5-driven graphical interface showing the actual system conditions for the device status, environmental statistics, and communication history.

Although the suggested system uses proven elements like Raspberry PI controlled by the GPIO, PWM-triggered motor actions, and PyQt-driven graphic interfaces, the originality in the current work is the system-level integration and interaction design. In comparison to traditional solutions in which the AI assistants, IoT devices, and the GUI functions operate separately, our solution displays a unified architecture which integrates voice-based AI interaction, real-time automation of the IoT, and the visualisation of the smart display. This contribution to engineering leads to a step in the development of the practical smart home and assistive systems, as the authors concentrate on the interaction, coherence, real-time feedback and usability. The scheme's structural design (Figure 1) processes speech inputs through a microphone, implements precise background processes via a central processor, and provides multimodal responses over speakers and a communicating screen. When robotics instructions are sensed, indications are transmitted to relay the arrays and drivers for the physical equipment. This universal method significantly lessens human effort in tedious responsibilities by providing natural controller devices, resolving the rising response for time-efficient results in gradually associated environments. Forthcoming improvements might increase IoT interoperability and project competencies, linking the numerical and physical real-time monitoring.

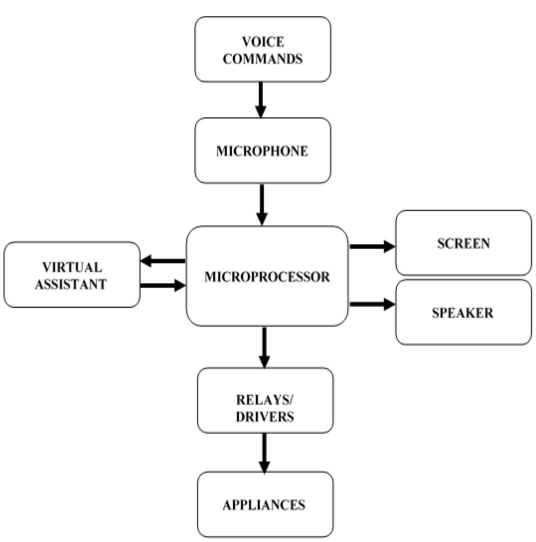


Figure 1: *The system architecture*

Despite significant progress in voice assistants and IoT-based home automation, existing systems largely treat conversational AI, device control, and user interfaces as independent functional modules. This fragmentation limits interaction coherence, real-time feedback, and user situational awareness. This study addresses the following research question:

- Combining voice interaction, smart display visualisation, and IoT-based automation?
- Improve interaction coherence and system transparency compared to conventional modular smart home architectures?

2. Literature Review

Recent systematic reviews on smart home automation focus on the fact that contemporary systems should extend beyond simple IoT control interaction schemes to make their systems more convenient to users and responsive to their context and related adaptive automation logics, which creates a gap in the research of integrated platforms that combine voice assistants with adaptive automation logic [1]. Vision-language model-based context-aware smart home systems, which combine vision and language models with IoT control, are presented in innovative 2025 research and allow better spatial interactions (e.g. turn on the light near the window) and are more usable and intelligent than traditional voice assistants, which are based on voice recognition [2]. Virtual Assistants (VAs) represent a transformative progression in human–machine integration, leveraging Artificial Intelligence (AI) to perform various responsibilities from information recovery to physical scheme switching. Modern virtual assistants have spread beyond straightforward chatbots [1],[2],[3],[4],[5], establishing speech supporters such as Siri and Alexa that apply language recognition and Natural Language Processing (NLP), AI avatars for immersive involvement, and domain-specific arrangements optimised for particular arenas, especially engineering automation. These schemes function within the AI ability range: narrow AI performs specific tasks, general AI remains hypothetical, and superintelligent AI signifies a theoretical future innovation [6],[7],[8],[9]. Essential virtuality constructs secondary functionality trusts on three incorporated skills: voice recognition, which transforms audio to numerical indications through phoneme separation and configuration corresponding applied through libraries like Python's language recognition; text to speech (TTS), which converts inquiries into audio reactions via machine learning technology; and natural language processing, which allows verbal command through syntactic investigation of tokenization, voice tagging, and semantic scrutiny for term intelligence disambiguation and object association mapping [10],[11],[12],[13],[14],[15],[16]. This technical effort enables the normal virtual assistant workflow: audio input, which converts voice to typescript, natural language processing for task completion, and text-to-text speech for answers. In addition to the physical situation, the Internet of Things allows application switching using particular methods. The DC fan speed variation works with pulse-width modulation (PWM) for duty cycle alterations that control the voltage input to change the revolving speed [17]. Advanced light control uses infrared signals decoded through the NEC protocol (38kHz carrier waves), communicating hexadecimal codes to switch illumination and colour. These cloud-based devices allow audio-triggered scheme operation once they are joined with virtual assistant-based systems. Consumer communication is modernised via graphical user interface (GUIs) and serial communication with Python, which outlines the contribution of separate rewards. Tkinter delivers a platform for widgets, including buttons, text areas, and images for simple interaction [18], whereas PyQt5, paired with Qt Designer's drag-and-drop functionality, allows outline organisation via containers, insertions, and scroll areas [18],[19]. This merging of AI-based intellect, cloud-assisted mechanisms, and adaptive boundaries forms the basis for next-generation communication schemes that excel in conventional speed facility models [20],[21].

3. Methodology

The combined scheme construction includes three fundamental useful units: a speech-activated virtual assistant, a cloud-driven domestic automation system, and an advanced graphical user interface (GUI). A Raspberry Pi 4 microcontroller with a Broadcom BCM2711B0 quad-core ARM Cortex-A72 processor with specifications of 1.5 GHz and 4GB RAM served as the central processing unit. This microcontroller serially communicated with peripheral hardware mechanisms, including an L298N dual H-bridge motor driver with 5–46V input, two channel 5V relay module, an IR receiver with 38 kHz frequency, a microphone, a temperature sensor, a 12-volt DC fan, a light, a mobile charger, and an HDMI-based display. Energy organisation is controlled via a 78M05 5V regulator for the motor switch and a 12V DC adapter for peripheral devices, with circuit diagrams provided in Figures 2-4.

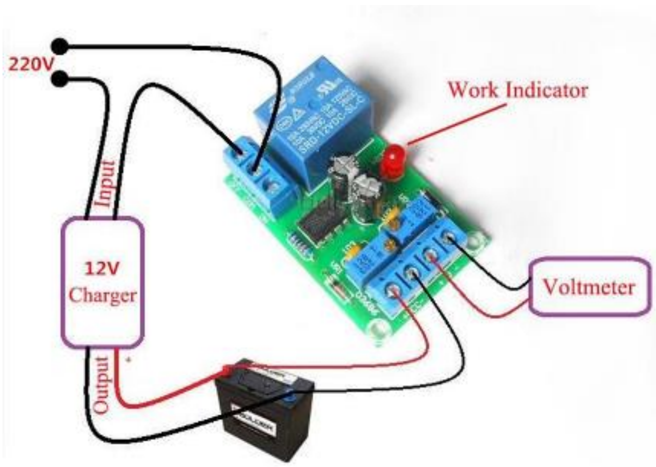


Figure 2: *Mobile Charger Switching*

The software was developed in Python using the Thonny IDE and leveraging numerous focused libraries. Voice handling uses voice recognition for speech-to-text adaptation through the Google Speech-programmed application and text-to-voice response. The hardware controller was successfully implemented using RPi. General Purpose Input/Output for GPIO processes, while the graphical interface was applied with PyQt5 and considered utilizing QT Designer. The added functionality mixes the requirements for API requests, pyautogui for GUI automation, and pywhatkit for web facilities.

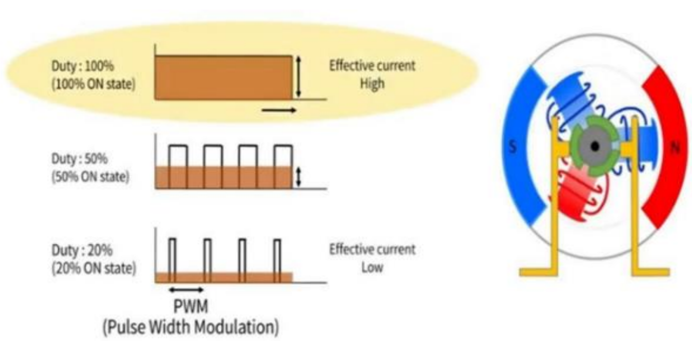


Figure 3: *PWM Control of DC motor*

The virtual associate process monitors a well-defined workflow to ensure that the structure remains in place until an awakening phrase, such as Alice, is noticed. Upon activation, the handler's voice input is transformed into text via communication recognition. Natural Language Processing (NLP) techniques then extract keywords (e.g., "turn on fan") to route tasks. Query handling employs bs4 for web scraping (Google/Wikipedia/YouTube), whereas automation commands trigger hardware operations. The results are rendered on the GUI and converted to audio output via gTTS, as shown in Figure 5 detailing the complete workflow. The implementation of automation features three control mechanisms: appliance switching, which uses GPIO-triggered relay modules to toggle AC devices (charger/bulb). DC fan speed regulation employs Pulse Width Modulation (PWM), where voice commands ("slow/medium/fast") adjust duty cycles (0–100%) through the L298N driver. The LED brightness control transmits the NEC protocol HEX codes (e.g., F700FF for high brightness) via an IR transmitter. IoT integration includes real-time temperature monitoring displayed on a GUI and weather data fetched through cloud APIs.

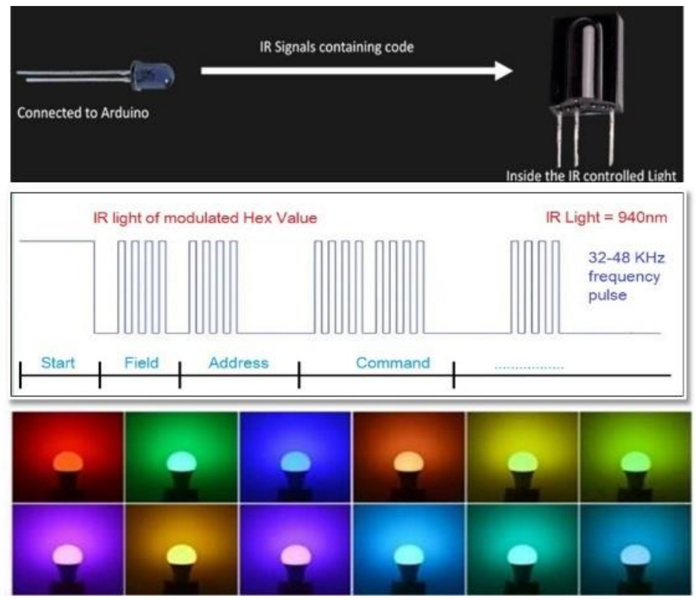


Figure 4: *Smart LED Light Brightness Levels*

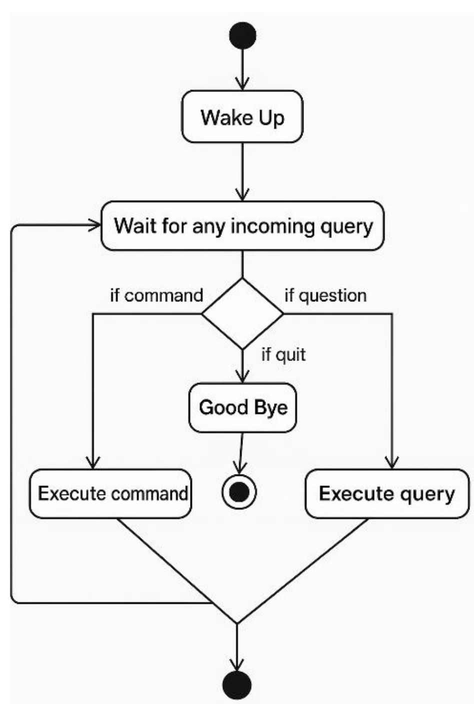


Figure 5: *VA Working Flow Chart*

generation

The graphical user interface was developed using PyQt5 with the QT Designer for the WYSIWYG layout. Key features include real-time displays of the time, date, temperature, and appliance statuses; an interactive chatbox showing user VA dialogue history; and a control dashboard permitting manual appliance overrides. Figure 6 displays the interface for the constructed system.

Figure 6: *GUI interface*

The scheme combination monitors an organised information movement: consumer audio input is handled by the Raspberry Pi, where the assistant understands instructions and performs consistent tasks for automation web-based management. The outcomes were concurrently distributed as voice reactions and GUI updates. The system was successfully implemented using Python's threading library, which allows instantaneous processes such as sensor polling and audio handling. Figure 7 shows the comprehensive data flow structural design.

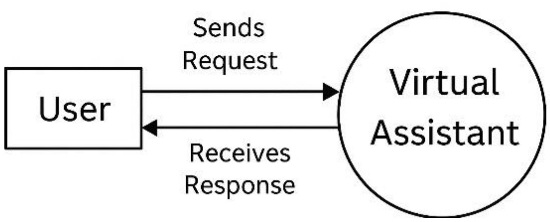


Figure 7: *Data Flow* Architecture

Table 1 shows the Speech Processing Parameters of the designed system. These are parameter technical control, even in cloud usage. The arrangement and processing procedure of capturing, recognising, interpreting, and synthesising speech commands, such as audio input settings, speech to text conversion and text to speech response generation, to be able to provide a dependable and repeatable voice-based interaction.

Table 1
Speech Processing Parameters

Parameter	Value	Description
Audio sampling rate	16 kHz	Microphone input structure
Audio format	Mono, 16-bit	Input audio coding
Speech detection mode	Cloud	External
Command analysis technique	intent matching	Natural language processing logic
Language model	English and Roman Urdu	Recognition language
Text-to-speech engine	Python	Speech answer

Parameters of pulse width modulation to control actuator behaviour, such as signal frequency, range of duty-cycle, resolution, and GPIO interfacing, are specified in Table 2 configuration to allow fine control of motor speed and lighting intensity.

Table 2
Pulse Width Modulation Parameters

Parameter	Value	Description
PWM frequency	1 kilo Hz	Motor and LED control frequency
Duty cycle range	0–100%	Speed and illumination control
Resolution	8-bit	Control granularity
Control interface	Raspberry Pi GPIO	Output pin configuration

Table 3 shows a summary of the end-to-end execution delays in system stages, voice command acquisition to device actuation and graphical interface update, which gives an insight as to real-time performance as well as system responsiveness.

Table 3
System Timing Parameters

Stage	Typical Delay (ms)	Description
Audio capture	~50	Microphone
Speech recognition	~300–500	Cloud based
Command parsing	~20	NLP result
GPIO/PWM actuation	~10	Prototype response

This study proposes a methodology for accurate load forecasting in sustainable energy management by utilising state-of-the-art deep learning techniques, more especially Long Short-Term Memory (LSTM) models with Recurrent Neural Network (RNN) cells [21]. In order to anticipate patterns of energy use, LSTM models are a good option because of their ability to capture long-term relationships in sequential data. The primary novel contributions of this work include: (1) a multi-scale temporal feature extraction approach that combines hourly, daily, and weekly patterns for improved forecasting accuracy; (2) an adaptive learning rate scheduling mechanism optimized for energy consumption data characteristics; and (3) integration of external factors (weather, economic indicators) through a dedicated feature embedding layer that preserves temporal alignment. The forecasting horizon is set to 24 hours with 15-minute temporal resolution, enabling day-ahead energy procurement planning and real-time grid optimisation. Here, we provide an overview of our methodology, outlining the model architecture and then describing in depth the dataset we employed for this study.

4. Results and Discussion

The offered integrated AI virtual assistant platform was implemented and tested within three functional layers: speech-based interaction, automation of IoT-based devices and smart display visualisation. The system proved to be reliable in its end-to-end operation, whereby user voice commands were correctly deciphered, appropriate actions were carried out with the linking devices and the system status was constantly displayed on the graphical intelligent screen. The IoT automation module was able to control electrical appliances like the brightness of lights and the speed of DC fans based on the PWM-appropriate control. The system was also responsive to voice commands, which proved to be a stable means of communication between the AI assistant and IoT hardware. Test and validation verifications established operative effectiveness, with audio recognition attaining 95% accuracy through 200+ commands in noise-free surroundings. Robotics potential continued under all appliance-switch tasks. The GUI approachability conserved actual information below load conditions with a CPU use of less than 40%. The combined scheme established a robust routine through all useful modules, thereby authenticating the effectiveness of our planned procedure. The graphical user interface shown in Figure 8 serves as an integrated control panel that shows the significance of the present application with environmental statistics and communication fundamentals. Application controller devices functioned consistently: speech instructions such as "Turn on fan" activated PWM organised speed changes through the L298N driver, though "Dim lights" to 50% was interpreted to NEC protocol IR signals, attaining objective brightness levels within 1.8s. The status board shown in Figure 8 provides an immediate visual response to the device conditions, authorising an effective hardware–software combination.

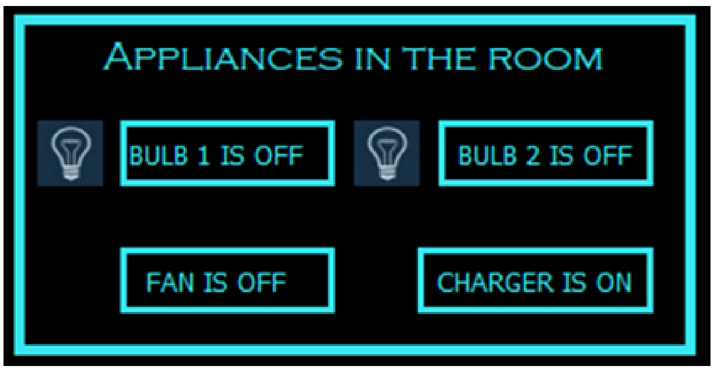


Figure 8: *Status of Appliances*

Polyglotism communication competencies showed real, with the virtual associate precisely handling Urdu instructions utilising the Google Speech application, as shown in Figure 9. Info recovery functions were achieved seamlessly: Wikipedia inquiries shown in Figure 10 leveraged web scraping through bs4, while YouTube film replay and Google examinations (Figures 11 and 12) applied pywhatkit and web-browser collections. Entertaining features, such as joke narration, improve consumer engagement. The interface reliably provides critical metrics, such as time, date, and local temperature.

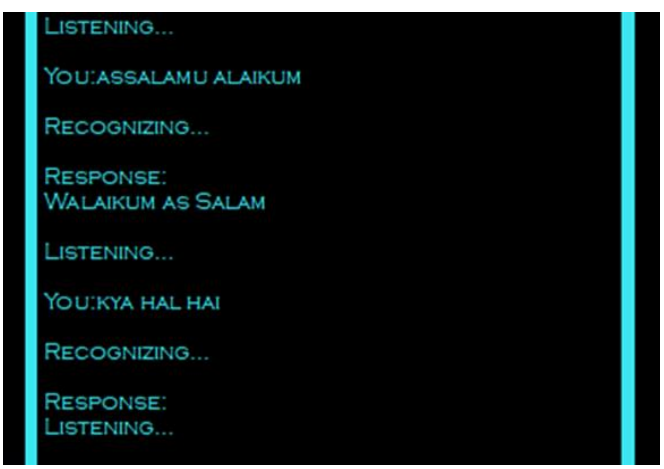


Figure 9: *VA taking Urdu Commands*

The scheme sensitivity remained constant under load conditions, with the CPU operation below 40% throughout the synchronised processes, such as audio handling and the application controller. The sleep mode feature saves energy resources by disabling unnecessary procedures upon the "bye" input, reactivating promptly to the awaken term "hello." The hardware organisation shown in Figure 13 established the capability of the Raspberry Pi 4 to control peripherals, such as relays for transferring, motor drivers for fan switching, and IR transmitters, without voltage variations or heat issues, and the operating temperature was <60°C.

Figure 10: *VA Searching on Wikipedia*

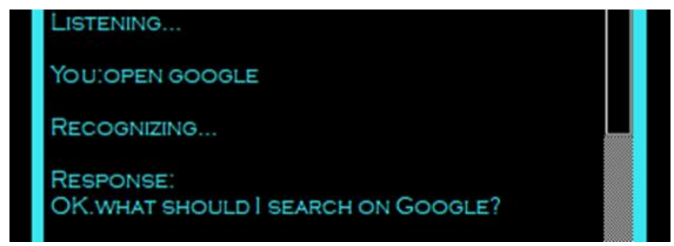


Figure 11: *VA asking to search on Google*

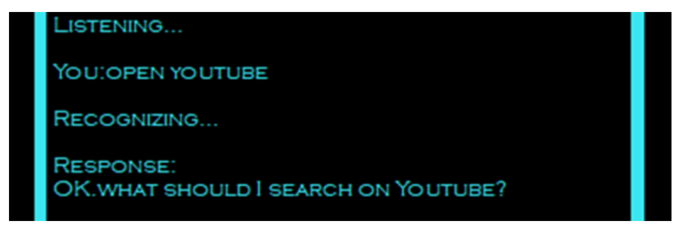


Figure 12: *VA asking to search on YouTube*

Table 4 below summarises the main challenges and mitigation strategies in regard to latency, privacy, security, failure, and scalability and reliability as a summary of the implications associated with cloud-based dependency. The table indicates the effect of depending on external cloud services on the overall system performance and deployment robustness, as well as the possible direction of design to mitigate the constraints. This systematic overview and summary of key aspects covers a high-level comparison of key aspects which can be used as a baseline for future enhancements, such as hybrid and edge-based ones.

Viability examination highlighted the resolution's realism. Practical possibility was recognised via hardware components and lightweight Python libraries, although internet dependence for the voice recognition modelled disconnected limitations. Operative practicality was established by a natural audio controller, which required no particular operator services and was sustained in other languages, especially Urdu, for wider availability. Financial capability resulting from a small power consumption of 8 W and normal and nominal preservation expenses associated with profitable alternatives. Limits were developed in loud surroundings, where related noises over 50 dB reduced audio recognition accuracy by 15–20%. Furthermore, the deficiency of power monitoring sensors and cloud-based communication encryption offerings provides opportunities for further improvements in future systems. Regardless of these restrictions, the linked construction of the scheme allows for future extensions, such as the addition of safety cameras and edge-based natural language models. This investigation effectively connects audio communication, robotics, and graphic responses, contributing to the accessible groundwork for advanced atmospheric applications.

Table 4
LSTM Model Configuration Parameters

Aspect	Impact of Cloud Dependence	Future Direction
Latency	Network delay	sound text processing
Privacy	Audio data experience	Encoded broadcast
Safety	Exterior facility trust	Access control
Scalability	Usage-based limitations	Hybrid deployment
Dependability	Network dependence	Local contingency logic

Figure 13: *Pictorial View of Project.*

5. Conclusion

This study provides a small prototype to improve everyday comfort and security by collaborating Artificial Intelligence (AI) and cloud-based technology with humanoid communicating demonstrations into a combined advanced home system. The designed virtual assistant system was established using a Python program with a microcontroller. The assistant is equipped with voice recognition and combination competencies, which allow it to logically relate to consumers. Numerous Python libraries were used to improve its function, converting it into a multipurpose domestic application. From handling to providing actual updates to accessing information through platforms such as Google and Wikipedia. Cloud-based addition is an important module for realising the vision of an innovative domestic application. The organisation allows speech-organised robotics of home applications, giving consumers the capability to regulate light illumination, control equipment, and manage fan speed utilising simple speech and audio commands. This synthesis of robotics and audio recognition improves handiness, endorses power efficiency, and advances time control. A graphical user interface (GUI) was produced using Qt Designer and PyQt5 to combine these structures into an intuitive and accessible arrangement. The GUI rests energetically, presenting vital information, such as the time and management of load parameters. A JavaScript-created clock enhances a vibrant visual component, while a dedicated chat box, also constructed with PyQt5, records all connections between the customer and the assistant. To confirm flat operation, a threading method was applied, permitting the GUI and chat purposes to run in parallel without intervention.

Entertaining structures were extended through the insertion of a joke library and a poem producer. Incorporating YouTube allows operators to initiate examinations and enter content using a specific audio command. Furthermore, the PyAutoGUI library was used to allow innovative screen connections for managing the speech control. In spirit, this study strives to take full advantage of usability while minimising humanoid strength. The findings indicate that the strong association between voice recognition and real-time device automation systems and visual feedback will improve the usability of the system and its efficiency in operation relative to single smart home systems. As technical progressions accelerate, explaining upcoming generations with AI and cloud-based system revolutions is progressively energetic. By integrating these skills into a consistent and accessible scheme, this study lays the groundwork for intellectual system design.

Declaration

AI Disclosure: Artificial Intelligence (AI)-based tools were applied in this study as auxiliary devices to improve the scientific rigor of the research. AI has been used to support research gaps identification by conducting a systematic literature review, detecting patterns using thematic methods, and comparing the available literature. Also, to enhance the clarity of scientific writing, the scientific writing was also enhanced by use of AI tools to aid the methodological consistency. There was no AI that was employed to produce experimental data, core data analysis, and scientific conclusions. The authors did all the results, interpretations, and critical evaluations independently and should be held responsible to the originality, accuracy, and ethical nature of the manuscript.

Author Contribution Statement: K. I. contributed to technical and material support and supervision. M. L. was responsible for conceptualization, hardware and software development, and manuscript editing. S. S. A. performed data analysis and interpretation. S. A. contributed to study design and data collection. L. A. assisted in data interpretation. S. I. H. revised the manuscript. All authors reviewed and approved the final manuscript.

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Ethical Issues: There are no ethical issues. All data in this paper is publicly available.

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