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Intelligent Smart Home Control Using NLP

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Abstract

The present research suggests an innovative smart home automation system using NLP and IoT technology, providing efficient control of household appliances through voice and text instructions. This system combines an NLP module with the Home module, offering natural communication between humans and devices without the need for pre-defined command set. The NLP module takes up the user commands by applying speech recognition, tokenization, intent classification, and entity extraction algorithms, whereas the Home module controls the appliances via Arduino UNO with the use of relays. Real time control of light, fan, and door in household environment becomes possible through text or voice communication. Experiments show that this approach is efficient in increasing the user convenience and accessibility, while decreasing dependence on complicated interfaces. The proposed intelligent automated control system is cost-effective to future intelligent smart home systems.

Keywords: Smart Home, IoT, NLP - Natural Language Processing, Voice Commands, Text Commands, Secure Home, Intelligent Smart Home.

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1. Introduction

Over the past few years, automation in smart homes has gained prominence due to the advances in technology and the need for increased convenience and energy efficiency. Through a smart home system, an individual is able to operate various processes within a house such as turning off lights and locking doors through voice command or texts which act as inputs for common tasks to enhance their efficiency [1]. Integration of smart home appliances with NLP has further resulted in smart homes operating at a much higher level where a user can operate the home appliance in a more convenient manner [2]. Traditional systems were limited to only manual or complicated operations which limited the use of smart homes to only a few users. This has however been overcome after integration with NLP which has enabled users to control appliances using natural language such as turning on the lights, calling out names of rooms, and the machine automatically carries out the operation based on these criteria. Therefore, there has been an increase in accessibility especially to aged and disabled people.

The development of new technological solutions, especially such as IoT and NLP, could potentially make the interaction between humans and various environmental objects more efficient; however, up until this point, it hasn't reached its full synergistic potential. IoT makes it possible for common household items, such as kitchen appliances or even cars, to be able to connect to the internet and thus change the way human beings use these objects. The implementation of IoT is most widely observed in the form of smart homes, which provide people with the ability to control the objects from anywhere and, therefore, improve the convenience and efficiency of energy usage [3]. This paper presents an innovative solution for a smart home automation project using IoT and NLP to make it possible to interact with different household appliances by using either text or verbal commands.

The advancement of smart homes has been substantial for facilitating daily activities, despite the numerous challenges that may limit its adoption and accessibility to the users. The continued need to interact with the devices using prescribed instructions and static interfaces creates difficulties since the devices may not be user-friendly. In cases where the device has voice-activated capabilities, users can engage with it without any physical contact but may face difficulties with handling variable commands and the intended meaning of what is said. To demonstrate significant improvement in the usability of the system, there should be an interface that can understand and learn the user's behavior and provide personalized assistance. There have been remarkable improvements in terms of how the systems are used in the house for daily activities. However, many of the problems that exist have remained a barrier to users achieving the system's full potential.

2. Literature Survey

The advent of smart home automation in conjunction with NLP technologies has changed the way humans interact with household gadgets. Initially, smart home solutions were oriented toward basic automation and preprogrammed operations. Yet, with the rapid advances in IoT, speech recognition and NLP technologies, intelligent voice-controlled solutions that are able to comprehend natural language and respond accordingly have appeared. This development brought higher levels of flexibility, accessibility, user-friendliness, and efficiency of smart home systems [4]-[6].

Further, the use of NLP technologies made interactions between smart home users and their gadgets more convenient. Speech recognition, intent detection, contextual comprehension and conversation management capabilities allow for easy control of household appliances using voice and text commands. Thus, it is evident that NLP technology made smart homes more flexible and friendlier to their users [7]-[10].

Privacy, reliability, and energy management are some other aspects that have been considered in recent studies. An offline smart home automation system equipped with ASR capabilities and power management functions has been suggested in [14]. The suggested system can be used for controlling home appliances using speech commands and monitoring energy consumption by not being connected with the cloud continuously, which enhances security and decreases dependence on cloud computing platforms. However, the suggested approach depends on the structure of commands, which restricts flexibility and energy efficiency.

A novel architecture for smart homes with the use of NLP and speech recognition algorithms in the edge, fog, and cloud computing paradigms has been proposed in [15]. The system makes use of intent-based voice recognition mechanisms to enable intelligent appliance control within resource-limited language domains. While the proposed solution enhances scalability and distributed computation, reliance on cloud computing might pose potential problems such as latency, operating costs, and data privacy. Furthermore, the designed prototype is applicable only within a particular language domain.

Table 1. Comparative Summary of Recent NLP-Based Smart Home Automation Systems

Reference	Functionality	Technology Used	Sensors Used	Microcontroller Used
Amit Kumar Kaiborta & Sarita Samal [1]	Voice-controlled home automation	NLP, Cloud Computing	DHT11, PIR, LDR, MQ-2	NodeMCU
Nandhini S & Rubla H [2]	Control of lights via voice	NLP, IoT	Smart Relays, Proximity, Motion	Raspberry Pi
P.A. Harsha Vardhini et al. [3]	Voice-activated electrical control	NLP, IoT, Wi-Fi	Temperature, Motion	Raspberry Pi
J. Paul Jasmin Rani et al. [4]	Hands-free smart home control	NLP, IoT, Bluetooth	Temperature, Humidity	NodeMCU
Farzeem D. Jivani et al. [5]	Voice control for lighting & security	NLP, IoT, Cloud	Motion, Light	ESP8266
Shubham Kumar & Shajulin Benedict [6]	AI-assisted smart home control	NLP, AI, IoTCloud	Temperature, Humidity, Motion	ESP32
Cyril Joe Baby et al. [7]	Voice-based control of appliances	NLP, IoT, Chatbot	Temperature, Gas, Motion	Raspberry Pi
Mithil K. M. et al. [8]	Voice-controlled lighting & cooling	NLP, IoT, Machine Learning	Temperature	Raspberry Pi 4
Vishakha D. Vaidya & Pinki Vishwakarma [9]	Smart monitoring and home security	GSM, IoT, Bluetooth, ZigBee	Motion, Smoke, Temperature	PIC Microcontroller
Arindom Chakraborty et al. [10]	Smart lighting and appliance automation	NLP, IoT, AI	Motion, Temperature, Humidity	Arduino Mega

Malkeet Singh & Anishkumar Dhablia [11]	Intelligent appliance control	IoT, Embedded Automation	Light, Motion	ESP8266
A. Shukla et al. [12]	Machine learning based smart automation	IoT, Machine Learning	Temperature, Motion, Gas	Arduino Uno
Yu-Hsiu Lin & Huei-Sheng Tang [13]	AI-enabled energy management system	AI, IoT, Neurocomputing	Temperature, Humidity, Energy Meter	ESP32

Above Table 1 highlighting key functionalities, underlying technologies, sensor configurations, and microcontroller platforms used across selected studies. In fact, technological innovations are emerging at a fast pace in the smart home sector, and their emergence continues to broaden the scope of application possibilities. Examples of trends include those ranging from voice-activated personal assistants to artificial intelligence-powered smart home control centers, which prove the concept and point toward a smarter, connected global home environment.

3. Methodology

The proposed system consists of two distinct modules, the Home Module, and the NLP Module. These two distinct modules work collectively to ensure proper control and automation of appliances and domestic devices. The Home Module serves as the intelligent interface between the domestic appliances, lighting, thermostats, door locks, and any other household appliance. The Home Module processes the request from the NLP Module and executes the required action on the specific appliance. The NLP Module handles all processing and understanding of the language used in the smart home automation system. Users can issue commands to the system using voice or keyboard commands. After receiving the command from the user, the NLP Module analyzes and understands each command made by the user and creates a suitable request or instruction which is sent to the Home Module.

3.1 Home Module

Home Module is the hardware component of the proposed smart home automation system. The module controls the operation of household appliances depending on the instructions issued by the NLP Module. Home Module consists of the following components – Arduino UNO, relay circuit, voltage regulator circuit, and communication circuit connected to the household appliances like light bulbs, fans, and door controllers.

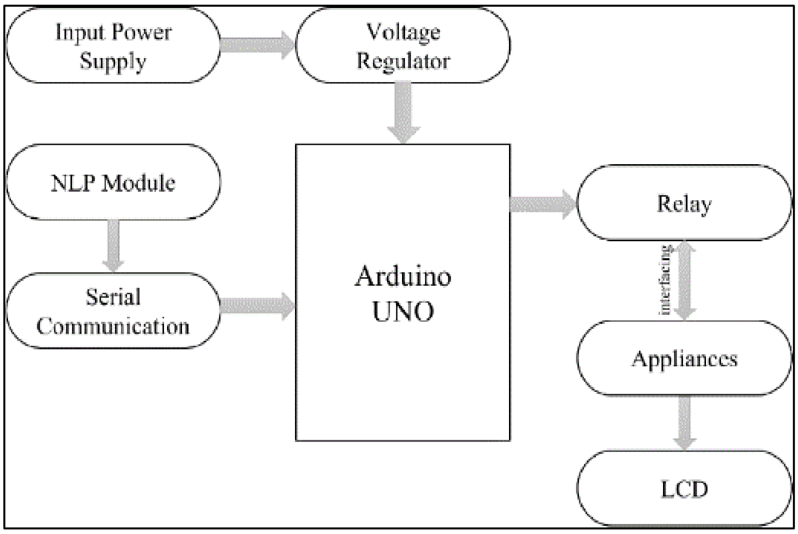

Figure 1. Block Diagram the Proposed Home Module for Appliance Control

As shown in Figure 1, Arduino UNO is a main component of this module that is utilized to control the operation of different devices. Relay circuit allows the user to switch household appliances safely. Voltage regulator circuit is included in the module to keep the process of operation of all the system elements stable. Serial communication is used for interaction between the two modules. The design of the Home Module provides efficient control of household appliances using simple hardware construction.

3.2 Natural Language Processing (NLP) Module

The NLP Module allows users to engage with the smart home system through voice or text instructions. It processes the received commands and transforms them into instructions for controlling the household appliances in the Home Module. The functionalities available in the module include user authentication, selection of modes, speech recognition, and natural language processing (see Figure 2).

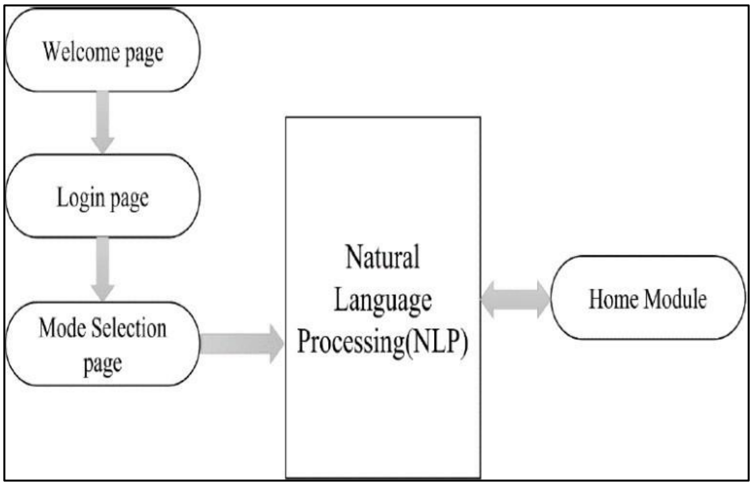

Figure 2. Block Diagram of the Proposed NLP Module for Smart Home Interaction

In order to understand the user command and execute it correctly, NLP is used, including operations like tokenization, text preprocessing, intent recognition, and entities extraction. The NLP Module can be implemented using Python libraries and allows both voice-based and text-based interaction. The processed command is sent to the Home Module for its implementation, and the feedback is generated at the same time. This new module will increase the convenience of users' interaction since there will not be any need for users to use any predefined command structure anymore.

3.3 Proposed NLP-Based Command Processing Algorithm

This algorithm integrates intent classification, entity extraction, and context management.

Algorithm: Smart Home NLP Command Interpreter

Input: User command (voice/text)

Output: Device control action

Step 1: Input Acquisition

Capture user input via:

Speech Recognition (voice mode)

Text Interface (text mode)

Step 2: Preprocessing

Convert speech to text (if voice input)

Apply:

Tokenization

Lowercasing

Stop-word removal

Lemmatization (improves over stemming used in the current system)

Step 3: Intent Classification

Use a trained model (e.g., Bi-LSTM / Transformer / lightweight neural network)

Classify input into predefined intents:

TURN_ON

TURN_OFF

SET_VALUE

STATUS_QUERY

Step 4: Entity Recognition

Extract key entities:

Device (light, fan, door)

Location (bedroom, kitchen)

Value (temperature, speed)

Example: "Turn on bedroom light" → Intent: TURN_ON, Entity: {device: light, location: bedroom}

Step 5: Context Handling

Maintain session memory:

Previous commands

Device states

Resolve ambiguous inputs: "Turn it off" → refers to last active device

Step 6: Confidence Evaluation

If confidence score < threshold (e.g., 0.75 as used in the system):

Ask for clarification

OR return fallback response

Step 7: Command Mapping

Map intent + entities → device instruction

Example:

IF intent = TURN_ON AND device = light AND location = bedroom

→ SEND: LIGHT_BEDROOM_ON

Step 8: Execution via Home Module

Send command through serial communication (Arduino/NodeMCU)

Activate relay/device

Step 9: Feedback Generation

Generate natural response:

"Bedroom light turned on"

Display via UI / LCD

Step 10: Continuous Learning (Optional Enhancement)

Log user commands

Update model periodically for personalization

3.4 Hardware and Software Components of the Proposed System

The proposed Smart Home Automation System will integrate both hardware and software elements for effective control of appliances through NLP. Table 2 presents the major hardware and software elements used in the proposed system alongside their functions.

Table 2. Hardware and Software Components used in the Proposed Smart Home Automation System

Component	Specification / Description
Arduino UNO	Main microcontroller used for appliance control and relay operation
Relay Module	Used for switching electrical appliances ON/OFF
Voltage Regulator	Converts 12V DC supply into regulated 5V DC
Light	Smart appliance controlled through NLP commands
Fan	Appliance controlled using relay interface
Gear Motor	Used for smart door control mechanism
Microphone	Captures user voice commands for speech recognition
LCD Display	Displays appliance status and system responses
Power Supply	Provides input power to the home automation module
Serial Communication Interface	Enables communication between NLP module and home module
Python	Programming language used for implementing the NLP system

PyTorch	Deep learning framework used for neural network implementation
NLTK Library	Used for tokenization, stemming, and NLP preprocessing

3.5 Implementation

The process of implementing the proposed smart home automation system involves the combination of NLP and appliance control by leveraging the Internet of Things. The working process of the proposed system is demonstrated in figure 3. The implementation of the system starts from user authentication whereby the entered login credentials will be validated prior to giving access to the control interface. Once the user is successfully authenticated, may choose text or voice mode to interact with the system. In case the text mode is selected, the user types the commands using the interface; if the voice mode is selected, speech commands will be entered via the microphone and translated into texts using speech recognition methods. The input command is analyzed through NLP tasks such as tokenizing, preprocessing, determining user intentions, and entity recognition.

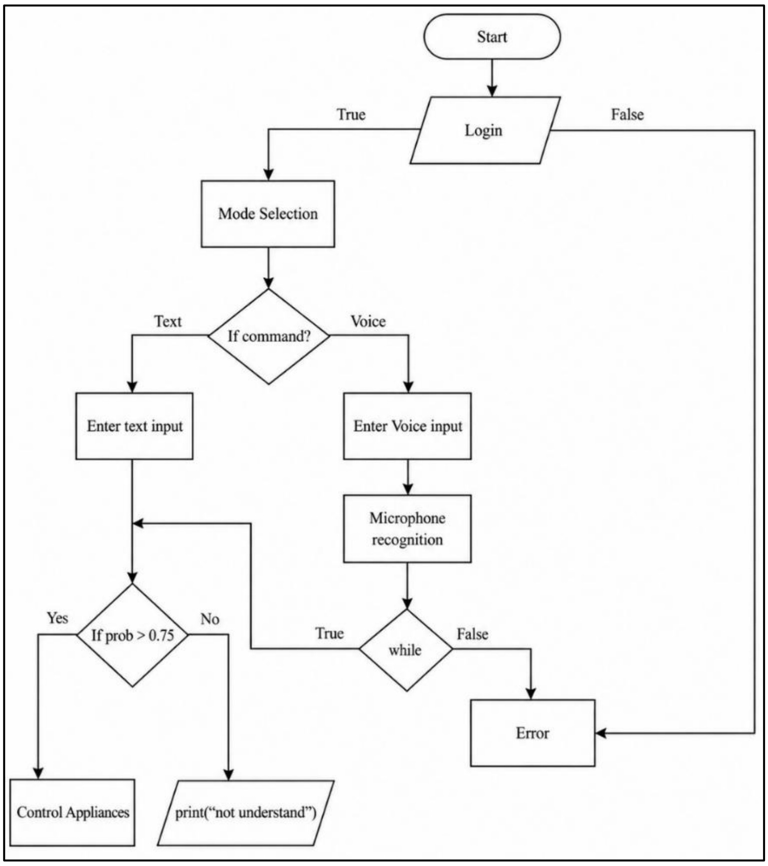

Figure 3. Operational Workflow of the Proposed NLP-Based Smart Home Automation System

The NLP model has been implemented with Python libraries such as NLTK, PyTorch, speech recognition, and serial communication library. The intent dataset that is stored in the file named 'intents.json' includes predefined patterns, tags, and response structures that help classify user command types. There is another file named 'data.pth', which stores a trained neural network model used for predicting user intent based on the input command.

In order to work with voice interactions, the system is always listening to user commands and transcribes the input speech into text. The text is then converted into a bag-of-words format and classified using the NLP model. Afterward, the confidence score generated from the model is validated using a threshold value of 0.75 to avoid unnecessary operation on appliances. If the confidence score meets the threshold value requirement, the corresponding command to control appliances will be sent via serial communication to the Home Module.

Communication with connected devices and processing of commands received via relay switch is carried out by the Home Module. At the same time, information about appliances' status is shown using both the graphical display and the LCD module. The system also contains error handling functionality in case of speech recognition errors or incorrect commands.

4. Results and Discussion

The proposed system combines NLP techniques with IoT-driven appliance control to enable smart communication between users and appliances. The hardware implementation of the proposed system is shown in Figure 4.

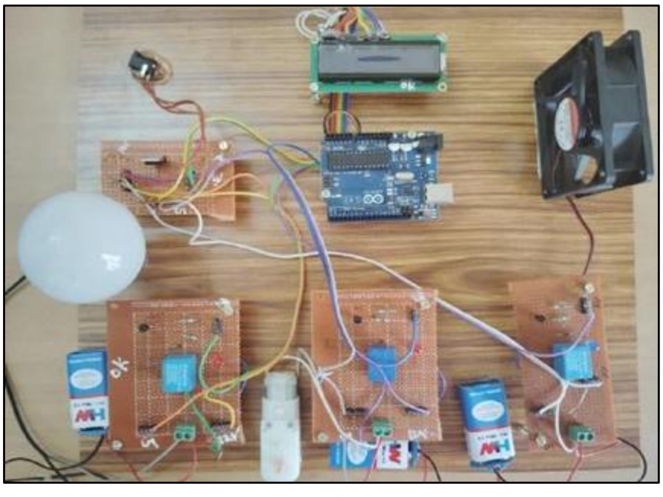

Figure 4. Hardware Implementation of the Smart Home Control System

The proposed solution proved to be successful at processing natural language commands using both textual and voice-based methods. The NLP Module executed the necessary pre-processing operations such as tokenizing, converting speech to text, recognizing intent, and assigning meaning to the command before sending the parsed command to the Home Module. The use of NLP technology helped to make the system understand user commands in a more intuitive and flexible way than in traditional pre-programmed command systems.

The graphical user interfaces created for the application are the Home Page, Login Interface, and Mode Selection Interface, which can be seen in Figures 5-7. The user interfaces facilitate easy and safe navigation within the smart home environment. The login process controls the unauthorized access.

Figure 5. User Interface of the Home Page

Figure 6. User Authentication Interface

4.1 Controlling Appliances Using Text Command

The mode selection interface (Figure 7) helps the user to select one among text command mode and voice command mode depending on their preferences. The performance of the text-based controlling was confirmed through conversational commands to operate appliances. According to Figures 8 and 9, conversational commands such as "Turn on the light" were understood and performed accordingly by the device. This was confirmed through the respective responses from the device, which were seen on both software and LCD interfaces. The natural language processing technology enabled flexible interaction between the users and the device.

Figure 7. Mode Selection Interface

Figure 8. Text-Based Command Input for Appliance Control

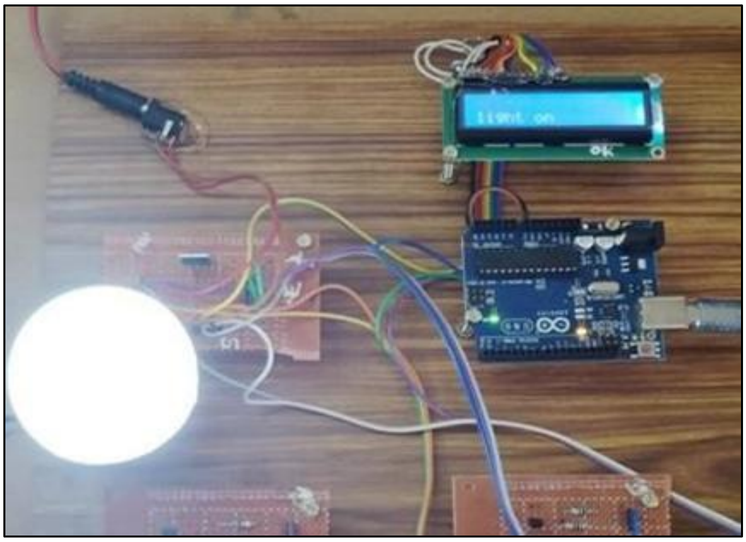

Figure 9. System Response and LCD Output for Text-Based Appliance Control

4.2 Controlling Appliances Using Voice Command

As seen from Figures 10 and 11, voice control proved to be an effective tool for speech recognition and appliance control. User voice input was recognized using speech recognition techniques in order to understand the user's intention and perform the necessary actions with respect to appliances. Response message outputs were issued following a successful action execution. Based on experimental results, the proposed method can increase accessibility and reduce user efforts and interaction times in smart homes.

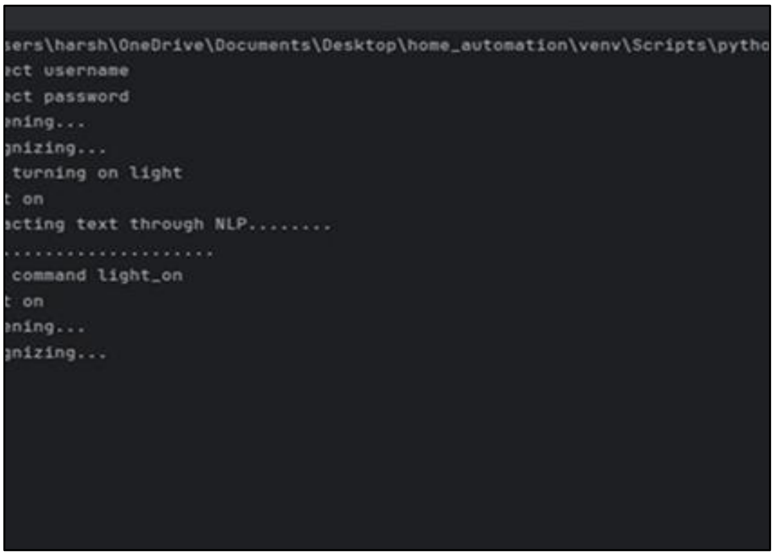

Figure 10. Voice Command Processing Interface of the Proposed System

Figure 11. System Response and LCD Output for Voice-Based Appliance Control

Overall, the implemented system provided robust appliance control, accurate command processing, and instant response generation. The use of NLP combined with IoT-based automation offers enhanced functionality and adaptability at minimal expense in terms of hardware intricacy and system development costs.

5. Conclusion

In this study, an intelligent system of automated smart homes using Natural Language Processing techniques and IoT has been discussed for efficient control over various household appliances using voice or textual commands. The suggested system comprises two main modules namely an NLP Module and a Home Module that are used for NLU and control and monitoring of various appliances respectively. The proposed system demonstrated efficient control of different appliances such as lights, fans, and doors with a convenient user interface. The application of various NLP techniques like speech recognition, tokenization, intent classification, and entity extraction made the process more flexible and efficient than previous command-based systems. Offline processing makes the proposed system cost-effective and scalable besides being privacy-preserving by eliminating cloud dependency. The future research on multilingual support and machine learning may further enhance its performance.

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