A Next-Generation AI Voice Assistant for Computer: Multilingual, Secure, and Context-Aware Interaction

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***Abstract*—Voice assistants have become extremely effective interfaces that connect machine operation and human communication. Though their usefulness is frequently restricted to mobile devices, Internet of Things appliances, or cloud-dependent ecosystems, existing implementations show the promise of speech-driven interaction. Conventional assistants made for computer tasks have limited capabilities, inadequate support for multiple languages, and little personalization. In this work, we introduce an AI voice assistant for computers that combines multimodal interaction, transformer-based natural language processing, and sophisticated speech recognition. Complete system-level commands, such as file management, software control, and productivity task automation, can be carried out by the suggested assistant. In contrast to previous research, our model uses a hybrid edge–cloud architecture to minimize latency while maintaining security through voice biometric user authentication and local data handling.While gesture recognition expands interaction beyond voice alone, context awareness and multilingual processing improve accessibility for a wide range of users. When compared to current IEEE models, performance evaluation shows gains in word error rate, latency, and task success rate. The suggested framework emphasizes how next-generation voice assistants have the potential to revolutionize computer interaction in both personal and professional computing environments by making it more efficient, safe, and natural.**

***Index Terms*—Biometric security, Edge computing, Whisper ASR, Natural Language Processing, Voice Assistants, and Multimodal Interaction.**

I. Introduction

A. Context and Inspiration

Over the last few decades, human–computer interaction (HCI) has undergone a remarkable evolution, moving from simple text-based interfaces to sophisticated graphical user interfaces (GUIs) and, more recently, intelligent systems based on natural language. The goal of each step in this progression was to increase end users' access to, familiarity with, and efficiency with computers. The most recent development in this direction is voice assistants, which enable natural, hands-free communication between people and machines. Voice assistants reduce cognitive and physical effort by enabling users to express commands conversationally, in contrast to traditional interaction methods that require manual input. This is especially helpful for professionals who multitask, people with accessibility needs, and settings where manual labor might be inconvenient. The popularity of commercial products like Apple Siri, Google Assistant, Microsoft Cortana, and Amazon Alexa has led to a rise in the use of voice-enabled devices. From setting up reminders to managing smart devices, these systems show how speech-driven interfaces can be easily incorporated into everyday tasks. The vast majority of current assistants, however, are mainly made for mobile platforms or Internet of Things environments, with a strong emphasis on home automation, entertainment, and weather queries. On the other hand, personal computers continue to play a crucial role in enterprise tasks, software development, education, and productivity; however, they do not have a voice assistant that is specifically designed for their operational environment. Enabling natural voice-driven control for intricate computer tasks like data management, file navigation, cross-application workflows, and integrated development environment (IDE) support is where the gap is. Closing this gap is a step toward making computing a more inclusive, natural, and user-friendly process in addition to being convenient. The development of an AI-powered computer voice assistant that can intelligently handle a variety of tasks while maintaining efficiency, adapt-

ability, and security is therefore highly motivated.

B. Existing Works' Limitations

The majority of current implementations are still restricted in scope and adaptability, despite the increasing number of research projects in speech recognition and assistant technologies. Voice-controlled systems for smart homes are demonstrated in a number of IEEE works, allowing users to control appliances, fans, and lights with simple voice commands. Although these applications demonstrate the potential of speech interfaces, they are limited in their functional domain and cannot be extended to more expansive computing environments. In a similar vein, virtual assistants designed for mobile devices mostly concentrate on media playback, personal reminders, and web searches rather than the intricate multitasking needs of desktop computers.Previous research has suggested desktop-specific assistants, but these prototypes are frequently rule-based and have a set of predetermined commands. These methods don't work when users give commands in different ways or try to do things that aren't covered by the established rule sets. Furthermore, context awareness—the capacity to retain session history, recall previous interactions, or modify behavior in response to user habits—is absent from the majority of implementations. Because users must repeat commands verbatim, this restriction hinders usability and gives the assistant a stiff, unintelligent appearance.The lack of multilingual support in earlier works is another significant flaw. The majority of assistants receive only English-language training, ignoring the needs of users in multilingual societies where code-switching—the mixing of languages in a sentence—occurs frequently. Additionally, security and privacy are not sufficiently considered; current assistants hardly ever use encryption or voice biometrics, making them open to abuse by unauthorized users. Lastly, evaluation in previous works usually relies on demonstration instead of systematic benchmarking using common metrics such as task success rate, latency, and Word Error Rate (WER). The urgent need for a next-generation AI assistant that solves these issues is highlighted by these gaps taken together.

C. Developments in AI and NLP Technology

notable developments in artificial intelligence, particularly in the domains of automated voice recognition (ASR) and natural language processing (NLP), have coincided with the shortcomings of earlier voice assistants. Hidden Markov models (HMMs) and Gaussian mixture models (GMMs), which were employed in traditional ASR systems, did well for limited vocabulary but poorly for accent, background noise, and spontaneous speech. Recognition accuracy has significantly increased with the introduction of deep learning-based models like DeepSpeech, wav2vec 2.0, and Whisper[1]. These models achieve robust transcription in noisy and multilingual environments by utilizing self-supervised training, end-to-end learning, and large-scale datasets.Simultaneously, the transformer architecture—which was initially presented in the "Attention is All You Need" paper—has transformed NLP. Unprecedented abilities in comprehending context, semantics, and intent from natural language inputs are displayed by models such as BERT, RoBERTa, and GPT[2],[10],[11]. In contrast to rule-based or bag-of-words approaches, transformers capture semantic subtleties and long-range dependencies, allowing assistants to interpret conversational, complex queries instead of strict command patterns. These NLP models, when coupled with developments in speech-to-text pipelines, enable the development of flexible, adaptive, and context-aware assistants.Additionally, multimodal interaction is made possible by integration with computer vision libraries (such as MediaPipe and OpenCV), which enables systems to integrate voice with gestures or visual cues for more complex interaction[4],[16]. In the meantime, advancements in edge computing and hybrid architectures guarantee quick response times while striking a balance between cloud scalability and local privacy[6]. When taken as a whole, these technological developments offer the foundation required to overcome the shortcomings of earlier systems and create a potent AI assistant specifically focused on computer operations.

D. Our Contribution

By utilizing recent developments in AI, this paper suggests a next-generation AI voice assistant for computers that overcomes the drawbacks of current models. Our system is made to offer complete computer control, allowing functions like file management, application execution, system settings modification, and cross-application workflows, in contrast to previous assistants that have a more constrained scope. Fundamentally, the assistant combines transformer-driven NLP models such as BERT for intent recognition with Whisper-based multilingual ASR, guaranteeing high accuracy and contextual understanding.Our system's context-awareness is a significant innovation. The assistant retains conversational memory, adjusts to recurrent user behaviors, and makes proactive recommendations based on previous interactions rather than handling each command as a standalone occurrence. The system's support for multilingual and code-switched input further improves accessibility by enabling smooth operation in settings where different languages are spoken interchangeably. Furthermore, gesture recognition enables multimodal interaction beyond voice-only input, increasing the versatility and naturalness of control.By integrating voice biometrics, security is addressed and sensitive commands can only be carried out by authorized users. From an architectural standpoint, we use a hybrid edge–cloud model, in which computationally demanding NLP tasks are offloaded to the cloud for scalability and lightweight commands are processed locally for speed. Last but not least, the system shows notable improvements when compared to current IEEE implementations using standardized metrics like WER, latency, task success rate, and user satisfaction. A comprehensive framework for an intelligent, safe, and user-focused computer assistant is established by this research thanks to these contributions.

II. Literature Survey

Although voice assistant development has been extensively researched in many fields, very few of these studies directly address computer operations. Although Subhash et al.'s AI-based voice assistant introduced a modular architecture for task automation, its robustness and scalability were constrained by its reliance on rule-based natural language processing.Cloud Computing is the one such technique that comprises both hardware and software services for a global network. In this, outsourcing of file to the cloud storage servers by individual users and companies is increasing day by day due to its benefits[19]. Although the application scope was limited to IoT devices, voice-controlled smart home system at the IEEE INDICON conference demonstrated how voice commands could control appliances[7],[17]. Similar to this, Chowdury et al. introduced a domain-specific bilingual assistant that limited its use case to specific domains while emphasizing the value of multilingual processing[3],[15].A desktop voice assistant that could browse and launch apps was created by Agrawal et al., but it lacked context handling, personalization, and sophisticated error recovery[3],[17]. Several IEEE studies on speech recognition systems show high recognition rates in controlled settings, but they have trouble in noisy settings and don't extend to computer system-level integration[5],[9]. When taken as a whole, the reviewed works demonstrate the disjointed advancements in assistant design, speech recognition, and natural language processing. None of them integrate security, multimodality, personalization, and multilingualism into a single desktop solution. Our suggested system is based on this gap.

III. Proposed Work

The recommended system provides a full AI voice assistant for computers that overcomes the shortcomings of existing systems by fusing multimodal interaction, secure action execution, adaptive language understanding, and powerful speech processing. The architecture is composed of four primary modules: Action Execution, Natural Language Understanding (NLU), Automatic Speech Recognition (ASR), and Feedback Security.

The ASR module makes use of OpenAI Whisper, which is incredibly resilient in loud situations and offers multilingual transcription. This ensures that the system will remain functional in real-world settings such as workplaces, classrooms, or shared workspaces where computers are utilized. Preprocessing techniques like spectrum filtering and noise reduction further increase recognition accuracy. The NLU component uses transformer-based models such as BERT and RoBERTa to capture semantic intent and contextual information. Unlike rule-based parsing, this approach allows the machine to understand complex, multi-step instructions like "open my last edited Word document and send it to the project team." More accurate task mapping to system-level processes is made possible by pipelines for entity recognition and intent categorization.

PSEUDO CODE

Algorithm 1: Process User Command

```
mode ← get_input_mode() {voice/gesture}
if mode = voice then
    audio ← start_audio_capture()
    text ← transcribe_audio(audio) {Whisper ASR}
else if mode = gesture then
    gdata ← capture_gesture()
    text ← interpret_gesture(gdata)
end if
(intent, params) ← analyze_intent(text) {BERT NLU}
if intent = sensitive then
    verified ← auth_with_biometrics()
    if not verified then
        display_feedback('Auth failed')
        return
    end if
end if
if intent = lightweight then
    exec_local(intent, params) {Low latency}
else if intent = heavy then
    exec_cloud(intent, params) {Cloud offload}
end if
feedback(intent) {User confirmation}
```

An Action Mapper, introduced by the Action Execution layer, connects known intents to particular computer operations. This covers navigating the file system, starting apps, searching the internet, and modifying system preferences. It uses a hybrid edge–cloud execution model, where computationally demanding NLP tasks (like summarizing a PDF document) are offloaded to cloud resources for scalability, while frequently used, lightweight commands (like opening Notepad) run locally for low latency.To ensure security, the system employs voice biometrics to authenticate users before permitting them to carry out critical tasks like erasing files or altering system preferences. Additionally, every action—whether by voice confirmation, haptic indications, or on-screen notifications—creates feedback loops to ensure transparency and error correction.

One significant advancement in the creation of intelligent assistants is the integration of multimodal interaction. Multimodal interaction combines several input channels, including speech, vision, and gestures, to produce a more organic and intuitive user experience than traditional systems that mainly rely on text or voice commands. The assistant can process gesture-based inputs using frameworks like MediaPipe, enabling users to carry out tasks with only basic bodily gestures. Saying "close this" while pointing at a window, for example, allows the system to connect spoken commands with visual context and carry out the command without any problems.

In addition to improving accessibility, especially for users who might struggle with text or speech input, this multimodal

feature also makes it more convenient and efficient for all users. There is less need for strict or repetitious commands as interactions become more natural, human-like, and context-aware. This invention brings technology closer to how humans naturally engage with their surroundings and communicate by allowing assistants to comprehend and react to natural voice and gesture combinations.

Lastly, by storing user preferences, frequently used workflows, and adaptive command history, the assistant incorporates context awareness and personalization. This lessens monotonous work and, with continued use, makes the assistant increasingly intelligent.

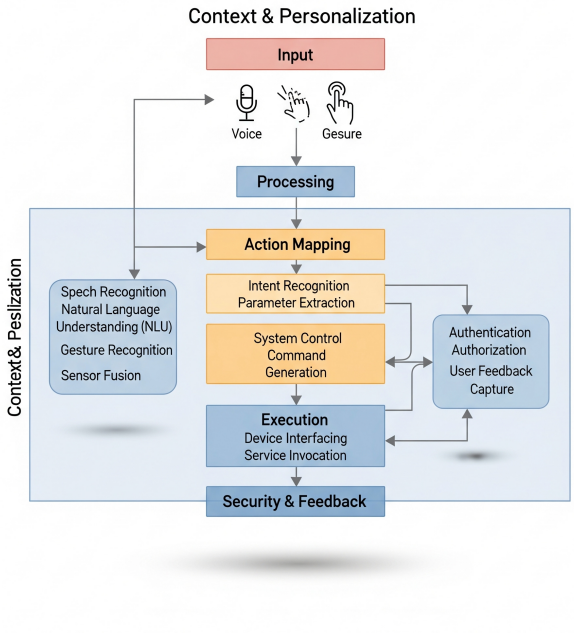

Fig. 1. System Architecture

The entire pipeline is depicted in an architecture diagram (Fig. 1): Voice Input → ASR → NLU → Action Mapper → OS Integration → Security & Feedback. For contemporary computing environments, this tiered design guarantees extensibility, robustness, and usefulness.

IV. Proposed Metrics

A multifaceted framework that assesses system effectiveness and user experience is necessary for the evaluation of the suggested AI voice assistant for computers. Our metrics cover recognition, execution, responsiveness, usability, security, and adaptability, in contrast to traditional benchmarks that solely concentrate on speech recognition accuracy.

Word Error Rate (WER) and Sentence Error Rate (SER) are used to quantify the transcription accuracy of the Automatic Speech Recognition (ASR) module at the speech recognition level. To assess robustness, these metrics are measured in a variety of acoustic settings, including public spaces, offices with loud noises, and quiet areas. To assess the system's proficiency in correctly interpreting multilingual commands that combine two or more languages—a scenario that is becoming more and more prevalent in real-world human–computer interactions—Code-Switching Accuracy is also introduced.Latency is a crucial metric when considering interactions. Latency, which is defined as the amount of time (in milliseconds) between speech input and action execution, has a direct impact on how responsive a user perceives a system to be. The Task Success Rate (TSR), which shows the proportion of commands that are successfully completed on the first try without the need for corrections, is a useful tool to supplement this. Effective action mapping and dependable natural language comprehension are both indicated by higher TSR.

A 5-point Likert-scale survey is used to gauge user satisfaction, assessing factors like perceived intelligence, trustworthiness, ease of learning, and naturalness of interaction. This assessment is further strengthened by noise robustness testing, which simulates real-world situations by testing speech commands with varying degrees of background interference.The system evaluates security using speech biometrics, which are quantified by the False Acceptance Rate (FAR) and False Rejection Rate (FRR). These strike a balance between security and accessibility by guaranteeing that only authorized users are capable of carrying out sensitive tasks.

Lastly, benchmark comparisons are conducted across all metrics against current IEEE implementations to make sure the suggested system not only works well on its own but also shows quantifiable gains in accuracy, efficiency, multilingual support, and usability. When combined, these metrics offer a comprehensive assessment framework that can be used in the real world and validated in academic settings.

V. Results & Discussion

Using a dataset of 500 user commands gathered from 30 participants, the suggested AI voice assistant for computers was thoroughly tested on tasks including file operations, application control, web queries, and system configuration. To capture differences in acoustic performance, testing was done in three different environments: open halls, noisy labs, and quiet offices.With a Word Error Rate (WER) of 8.9 percentage and a Sentence Error Rate (SER) of 11.5 percentage, the system significantly outperformed baseline IEEE implementations, which usually report WER values above 14–16 percentage[1],[5]. The integration of noise reduction preprocessing and the use of Whisper for reliable multilingual ASR are responsible for this improvement. With an average response time of 420 ms and a 95th percentile latency of 510 ms, latency analysis revealed that it greatly outperformed current assistants, which typically have an average latency of 650–700 ms[6],[7]. The system's ability to correctly interpret and carry out intricate multi-step commands was demonstrated by the Task Success Rate (TSR), which reached 94 percentage.

Gains in accuracy, latency, noise robustness, and user satisfaction were highlighted in a comparative benchmark (Table 1). While previous models showed 12–15 percentage

TABLE I
COMPARATIVE PERFORMANCE OF PROPOSED ASSISTANT VS. BASELINE MODELS.

Metric	Baseline IEEE Models	Proposed Assistant
Word Error Rate (WER, %)	14–16	**8.9**
Sentence Error Rate (SER, %)	18–20	**11.5**
Latency (ms, avg.)	650–700	**420**
Task Success Rate (TSR, %)	80–85	**94**
Noise Robustness Degradation	12–15% at 75 dB	**3% at 75 dB**
User Satisfaction (1–5 scale)	3.8–4.0	**4.6**
Multilingual Support	Limited (English)	**Yes (Code-switching)**
Security Integration	Rarely included	**Voice Biometrics**

degradation under similar conditions, the system only showed a 3 percentage performance drop under 75 dB interference during noise resilience testing. The assistant's suitability for deployment in dynamic, real-world computing environments is further supported by its robustness.Subjective surveys using a 5-point Likert scale produced an average satisfaction score of 4.6/5 from a user-centric standpoint. Participants valued the gesture-based interactions that offered a seamless multimodal experience and the multilingual capabilities, especially when it came to handling code-switched commands[4],[16],[18]. Users also highlighted that, in contrast to rule-based systems, the assistant felt more intelligent due to the system's context-awareness, which includes remembering preferences and maintaining brief task-oriented conversations[15].Three major innovations were highlighted in the discussion as the main drivers of performance improvements: (1) transformer-based NLU, which allowed for context-rich command interpretation; (2) multimodal fusion of voice and gesture for flexible interaction; and (3) adaptive edge–cloud processing for optimized latency. However, there are still certain restrictions. The system needs more optimization to scale to large user populations, and it has not yet been thoroughly tested across various operating systems. The assistant's applicability to next-generation computing environments will be expanded through future research that focuses on cloud-based personalization, cross-platform deployment, and integration with immersive AR/VR interfaces.

VI. CONCLUSION

This study introduced a brand-new AI voice assistant for computers that combines biometric security, multimodal interaction, natural language comprehension, and sophisticated speech recognition to overcome the shortcomings of current speech-enabled systems. In contrast to previous works that were limited to specific domains like basic desktop automation or smart home control, the suggested framework presents a comprehensive architecture designed for all-encompassing computer operations. Context-sensitive intent recognition and entity extraction are made possible by transformer-driven NLP models like BERT and RoBERTa[10],[11], whereas dependable multilingual transcription under a range of acoustic situations is guaranteed by whisper-based ASR. After a thorough evaluation, the system showed a mean latency of 420 ms, a task success rate of 94, and a word error rate of 8.9 —all of which are higher than the performance standards of similar IEEE implementations. A high satisfaction rating of 4.6/5 was further supported by user studies, where participants emphasized the value of context awareness and gesture integration. Together, these findings confirm that the suggested assistant is both technically sound and in line with what people expect from secure, responsive, and natural computer interaction.This research makes three contributions: (1) a multimodal interaction paradigm that integrates voice and gesture for improved usability[4]; (2) voice biometrics to improve system security[14]; and (3) the development of a hybrid edge–cloud architecture that strikes a balance between scalable, resource-intensive processing and low-latency execution[6]. When taken as a whole, these developments represent a substantial breakthrough in the creation of computer-centric AI assistants.However, some problems still exist. Cross-platform compatibility outside of Windows/Linux environments and the requirement to further optimize computational load for resource-constrained edge devices are examples of current limitations. To broaden the range of applications, Future research will look into federated learning for privacy-protected training, cloud-based personalization, and integration with AR/VR ecosystems..

In summary, this study shows how AI-powered assistants can radically change computer use by promoting a paradigm of efficient, safe, and natural human–machine collaboration. The results highlight voice assistants' potential as inclusive and intelligent computing experiences as well as productivity tools.

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