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Innovative Personal Assistance: Speech Recognition and NLP-Driven Robot Prototype

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A B S T R A C T

This paper presents the development and evaluation of a personal assistant robot prototype with advanced speech recognition and natural language processing (NLP) capabilities. Powered by a Raspberry Pi microprocessor, it is the core component of the robot's hardware. It is designed to receive commands and promptly respond by performing the requested actions, utilizing integrated speech recognition and NLP technologies. The prototype aims to enhance meeting efficiency and productivity through audio-to-text conversion and high-quality image capture. Results show excellent performance, with accuracy rates of 100% in Indonesian and 99% in English. The efficient processing speed, averaging 9.07 seconds per minute in Indonesian and 15.3 seconds per minute in English, further enhances the robot's functionality. Additionally, integrating a high-resolution webcam enables high-quality image capture at 1280 x 720 pixels. Real-time integration with Google Drive ensures secure storage and seamless data management. The findings highlight the prototype's effectiveness in facilitating smooth interactions and effective communication, leveraging NLP for intelligent language understanding. Integrating NLP-based speech recognition, visual documentation, and data transfer provides a comprehensive platform for managing audio, text, and image data. The personal assistant robot prototype presented in this research represents a significant advancement in human-robot interaction, particularly in meeting and collaborative work settings. Further refinements in NLP can enhance efficiency and foster seamless human-robot interaction experiences.

INTRODUCTION

Artificial intelligence (AI) and robotics advancements have transformed how humans interact with technology [1]. Personal assistant robots, in particular, have emerged as groundbreaking solutions capable of revolutionizing our daily lives [2]. These robots possess the ability to understand and respond to human speech, translating verbal commands into actionable tasks [3]

At the core of personal assistant robots lies Natural Language Processing (NLP), a subfield of AI that enables machines to comprehend and interpret human language [4]. Leveraging the power of NLP, personal assistant robots can accurately recognize speech patterns, extract meaningful information, and generate appropriate responses [5]. This technology is the foundation for developing the innovative personal assistant robot prototype [6].

Meetings and collaborative work environments are domains ripe for significant impact from personal assistant robots [7]. In today's fast-paced and interconnected world, efficient communication and productivity during meetings are vital for organizational success [8] [9]. However, challenges such as note-taking [10], action item tracking, and documentation can hinder the flow of meetings and impede post-meeting productivity.

Addressing these challenges, this research introduces an innovative personal assistant robot prototype that utilizes speech recognition and Natural Language Processing (NLP) to enhance meeting efficiency and productivity. The primary objective of this study is to create a sophisticated, user-friendly robot capable of recording voice inputs, converting them into written text, capturing images, and seamlessly uploading the data to cloud storage for easy access and retrieval.

Users can issue voice commands by integrating speech recognition technologies [11] within the personal assistant robot. The robot promptly responds with an acknowledgment message, indicating its readiness to capture and process speech inputs [12]. This eliminates manual note-taking [13], allowing participants to focus on discussion and idea exchange.

The robot converts recorded speech into text using advanced NLP algorithms, effectively transforming spoken language into written form [14]. This enables the automatic generation of meeting transcripts, providing valuable references for participants to review discussions, extract action items, and follow up on critical decisions made [15] during the meeting. Additionally, the robot can capture images to support documentation processes.

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To streamline data management and accessibility, the prototype is designed to automatically upload recorded voice files, transcriptions, and captured images to a cloud-based storage system [16], namely Google Drive. This approach ensures secure storage [17], easy availability [18], and effortless sharing of meeting-related information [19] among participants. The manual organization and distribution of meeting materials are eliminated, saving time and effort for all involved.

This research aims to contribute to personal assistant robotics by introducing a prototype that leverages speech recognition and NLP technologies to enhance meeting efficiency and productivity. This innovative robot enables seamless collaboration, efficient post-meeting follow-ups, and improved productivity by automating note-taking, transcription, and documentation processes.

In conclusion, this research's personal assistant robot prototype represents a significant advancement in human-robot interaction, particularly in meeting and collaborative work settings. By harnessing the capabilities of speech recognition and NLP, this innovative robot offers a versatile and intuitive interface, enabling users to convert speech to text, capture images, and effortlessly manage meeting-related data.

METHOD

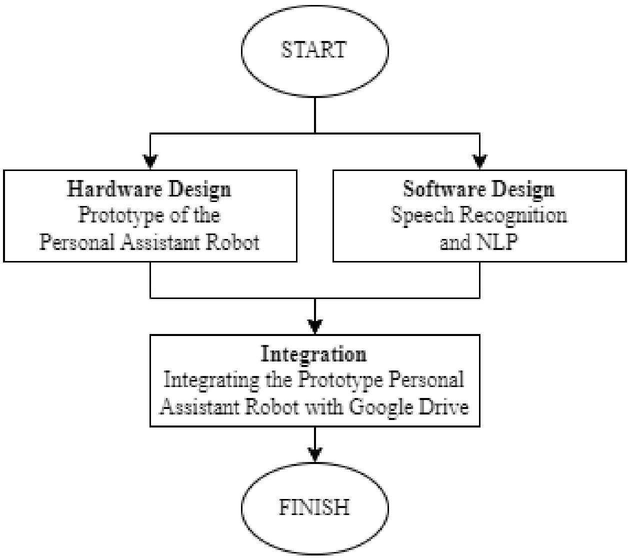

Figure 1. Device Design

A careful and comprehensive approach was used to facilitate the development and evaluation this innovative personal assistant robot prototype. The device design process is represented as a flowchart in Figure 1, divided into three stages: hardware design, software design, and integration. Each step plays an essential role in shaping the overall development and functionality of the personal assistant robot prototype. The following sections give a detailed description of each stage, highlighting the vital steps undertaken.

Hardware Design

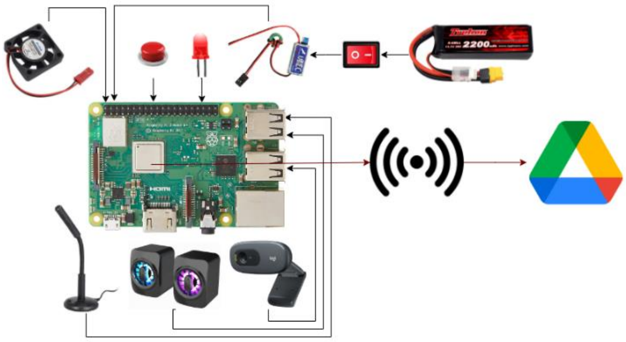

Figure 2. Hardware Design

The hardware design of the personal assistant robot prototype revolves around the careful selection and integration of various components to ensure optimal functionality and performance. Key features utilized in the hardware design include the Raspberry Pi 3B+, speaker, microphone, webcam, cooling fan, push button, LED, UBEC, switch, and a 3-cell battery.

At the core of the hardware design lies the versatile Raspberry Pi 3B+, which serves as the robot's central processing unit [20]. This microcomputer provides the computational power, connectivity options, and compatibility necessary for the robot's functionalities.

For seamless voice communication, the prototype incorporates a speaker and a microphone. The speaker enables the robot to deliver audible responses and engage in speech-based interactions with users [21]. Meanwhile, the microphone facilitates voice input [22], allowing the robot to understand and process spoken commands.

To capture images, a webcam is integrated into the hardware design [23]. This camera module enables the robot to acquire visual data and images, which can be used for documentation or optical recognition tasks.

A cooling fan is included in the design to prevent overheating and ensure optimal performance [24]. This fan helps maintain a stable temperature for the Raspberry Pi, promoting its longevity and efficient operation.

A push button to stop the recording process. This push button is a user-triggered control [25] to terminate the robot's audio recording feature.

An LED indicator is also integrated into the design, providing visual feedback on the robot's status. The LED can be programmed to convey operational states [26], such as whether the robot is turned on or off.

A UBEC, which acts as a voltage regulator [20], facilitates power supply regulation, ensuring a stable and reliable power output between the battery and the Raspberry Pi.

To manage power effectively, a switch is incorporated to control the power flow between the UBEC and the 3-cell battery. This switch offers convenient on/off functionality [27] and helps conserve power when the robot is not in use.

Finally, a portable and rechargeable 3-cell battery is included to provide the power supply for the personal assistant robot. This battery enables the robot to operate without relying on a constant external power source, enhancing its mobility and versatility [28].

The seamless integration and careful arrangement of these components form the foundation of the hardware design for the personal assistant robot prototype.

Software Design

The software design of the personal assistant robot prototype encompasses a sophisticated speech-to-text conversion process. This process consists of multiple stages, each contributing to the precise transformation of voice input into textual output, as seen in Figure 3.

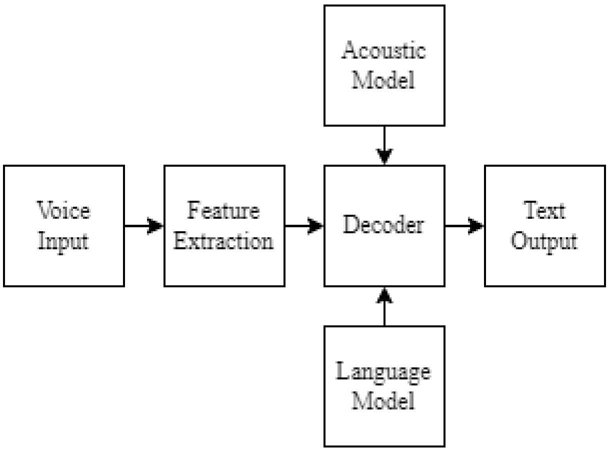

Figure 3. Speech-to-Text Processing Block Diagram

The initial stage involves capturing spoken language through the robot's microphone [29], serving as the foundation for subsequent processing. The captured audio signal is then subjected to feature extraction, where essential acoustic characteristics, such as Mel-frequency cepstral coefficients (MFCCs) or filter banks [30], are analyzed and extracted. These features capture crucial aspects of the voice input, laying the groundwork for further analysis.

The decoder stage is pivotal in converting the extracted features into text output. Comprising the acoustic and language models, the decoder leverages sophisticated algorithms to establish associations between acoustic characteristics and phonetic units [31]. The system effectively maps the voice input to probable phonetic sequences by discerning the statistical relationships.

Simultaneously, the language model complements the decoder by providing contextual information [32]. This model captures statistical patterns and probabilities of word sequences within a given language. By incorporating the language model, the system gains a deeper understanding of likely word sequences, enhancing the overall accuracy of the final text output.

The culmination of these stages results in the generation of a transcribed textual representation of the original voice input. Drawing upon the information from the acoustic and language models, the system produces a sequence of words that accurately reflects the spoken language. This text output can be further processed, analyzed, and seamlessly integrated with other personal assistant robot prototype functionalities.

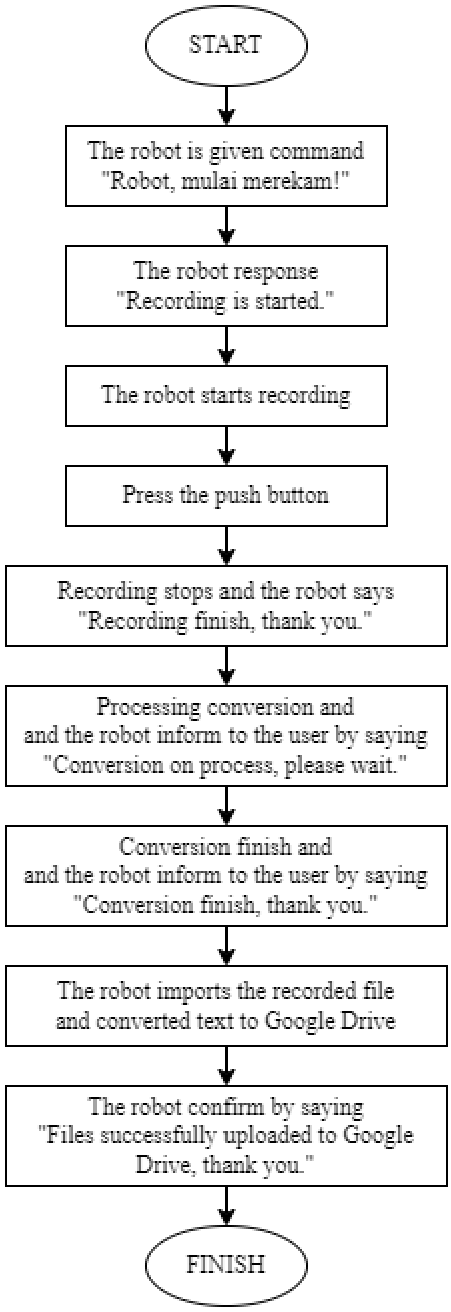

Figure 4. Recording Process

The presented flowchart comprehensively visualizes the sequential stages encompassed within the recording process. It guarantees a structured and streamlined workflow, enabling the personal assistant robot prototype to capture audio effortlessly, transform it into written text, and securely store the resulting files in Google Drive. This systematic approach ensures both efficiency and convenience, allowing for convenient retrieval and facilitating subsequent analysis and evaluation of the recorded data.

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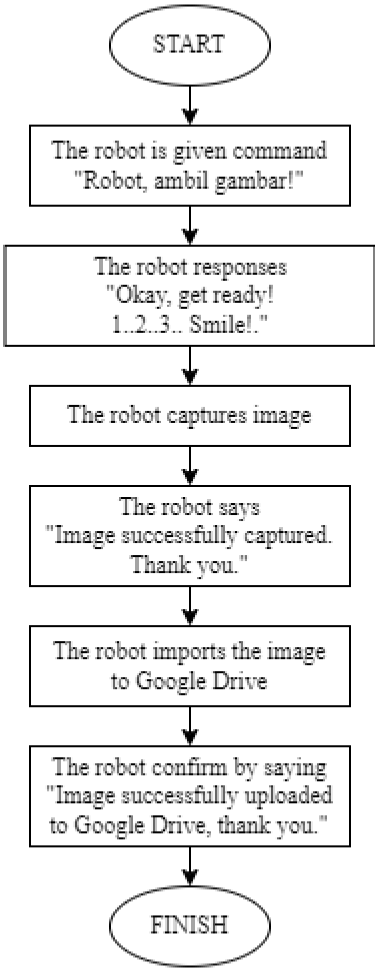

Figure 5. Image Capture Process

The depicted flowchart is a lucid depiction of the successive stages of the image capture process. It guarantees a seamless and effective workflow, empowering the personal assistant robot prototype to effortlessly acquire images and securely store them in Google Drive for convenient retrieval and accessibility. This systematic approach ensures a harmonious integration of image capture functionality, allowing for streamlined operations and effortless visual data management.

Integration

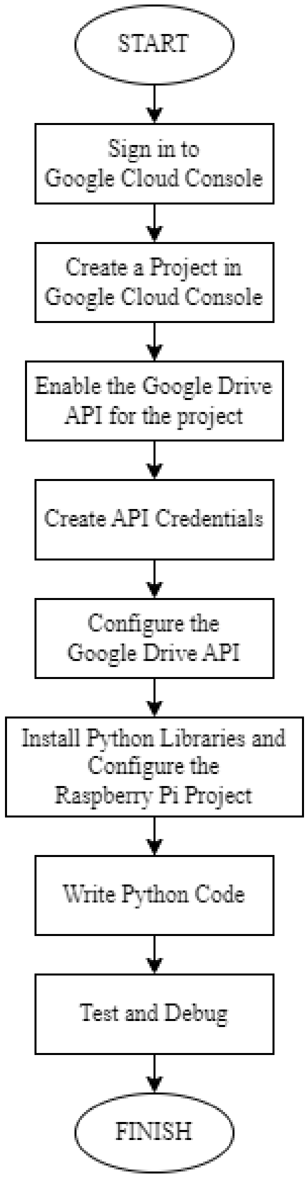

Figure 6. Integration Process

The integration flowchart concisely represents the steps in seamlessly connecting the Raspberry Pi with Google Drive. It encompasses essential stages, including signing in to the Google Cloud Console, creating a new project, enabling the Google Drive API, generating API credentials, configuring the API settings, installing necessary Python libraries, writing code to facilitate the integration, conducting comprehensive testing, and addressing any potential issues through debugging. This systematic approach ensures the successful integration of the Raspberry Pi with Google Drive, enabling seamless data transfer and synchronization.

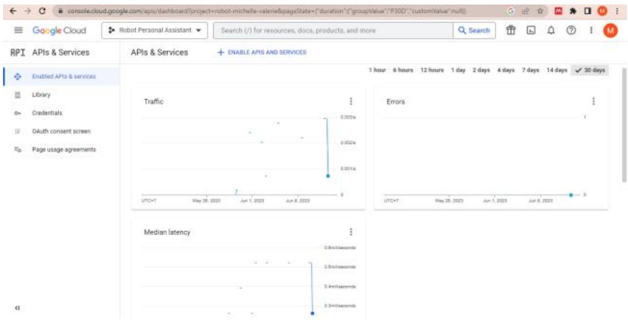

Figure 7. Google Cloud Console

Figure 7 displays the "Enable APIs and services" section in the Google Cloud Console, showcasing graphs depicting data traffic, errors, and latency metrics. These visual representations offer insights into the performance and effectiveness of integrating the hardware and Google Drive. The traffic graph illustrates the volume of data requests or accesses over a specific period. The error graph demonstrates the number of errors or failures encountered during API interactions. Meanwhile, the latency graph showcases the system's response time in processing requests and delivering responses. Through the Google Cloud Console, users can meticulously monitor and analyze the integration's performance, proactively identifying and resolving any issues that may arise to ensure smooth and efficient operations.

RESULTS AND DISCUSSION

Table 1. System Responsiveness

No.	Test Item	Result		Description
		Yes	No	
1.	Does the prototype robot personal assistant respond with "Recording is started" when given the command "Robot, mulai merekam!"?	✓		The prototype robot personal assistant promptly responds with "Recording is started" when instructed to start recording, ensuring efficient communication between the user and the device.
2.	Does the prototype robot personal assistant initiate recording after stating, "Recording is started"?	✓		Upon announcing "Recording is started," the prototype robot personal assistant initiates the recording process promptly, allowing for seamless and timely audio capture.
3.	Does the prototype robot personal assistant stop recording when pressing the Push Button?	✓		The prototype robot personal assistant effectively stops recording when the Push Button is pressed, giving users control over the recording process.
4.	Can the prototype robot personal assistant convert the recorded audio into text?	✓		The prototype robot personal assistant demonstrates its ability to accurately convert recorded audio into text, allowing users to access and analyze the recorded information conveniently.
5.	Can the prototype robot personal assistant convert Indonesian language recordings into text?	✓		The prototype robot personal assistant exhibits proficiency in converting recordings in the Indonesian language into text, facilitating effective communication and understanding.
6.	Can the prototype robot personal assistant convert English language recordings into text?	✓		With its advanced language processing capabilities, the prototype robot personal assistant successfully converts recordings in the English language into text, ensuring seamless interpretation and comprehension.
7.	Does the prototype robot personal assistant respond with "Okay, get ready! 1.. 2.. 3.. Smile!" when given the command "Robot, ambil gambar!"?	✓		When commanded to take a picture, the prototype robot assistant responsively replies, "Okay, get ready! 1.. 2.. 3.. Smile!" ensuring a delightful and engaging user experience.
8.	Does the prototype robot personal assistant capture an image after stating, "Okay, get ready! 1.. 2.. 3.. Smile!"?	✓		Following the prompt, the prototype robot personal assistant skillfully captures images, providing users with explicit and visually appealing visual content.
9.	Can the prototype robot personal assistant send the recorded files, text, and images to Google Drive?	✓		The prototype robot personal assistant effectively transfers recorded files, text, and images to Google Drive, facilitating secure storage and

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			convenient access to the captured data.
10.	Can users access the recorded files, text, and images on Google Drive?	✓	Users can seamlessly access the recorded files, text, and images stored on Google Drive, ensuring easy retrieval and utilization of the captured information.

In Table 1, the system responsiveness of the personal assistant robot prototype is evaluated based on its promptness and efficiency in various tasks. These evaluations highlight the personal assistant robot prototype's responsiveness and efficiency in performing key tasks, ensuring a positive user experience and enabling effective data management.

Table 2. Processing Speed for Indonesian Audio-to-Text Conversion

No.	Recording Duration	Processing Time
1.	1 min	12 secs
2.	2 mins	20 secs
3.	3 mins	33 secs
4.	4 mins	40 secs
5.	5 mins	51 secs

Table 2 presents the evaluation of audio-to-text conversion speed in the Indonesian language. The data reveals an average conversion time of 9.07 seconds per minute, highlighting the remarkable efficiency of the speech recognition system in swiftly and accurately transcribing audio recordings into written text in Indonesian.

Table 3. Speech Recognition Accuracy in Indonesian

No.	Recording Duration	Words Count in Recording	Number of Words Successfully Converted	Accuracy Rate
1.	1 min	102	102	100%
2.	2 mins	161	161	100%
3.	3 mins	305	305	100%
4.	4 mins	385	385	100%
5.	5 mins	428	428	100%

Table 3 showcases the accuracy of the speech recognition system in the Indonesian language, exhibiting the number of words in the recordings and the corresponding successfully converted words. The data showcases an impressive average accuracy rate of 100%, underscoring the system's exceptional ability to transcribe spoken words into written text in Indonesian precisely.

These findings underscore the exceptional performance of the personal assistant robot prototype's speech recognition capabilities in Indonesian. With its swift processing speed and high accuracy, the system ensures dependable and precise audio conversion into text, bolstering effective communication and comprehension.

Table 4. Processing Speed for English Audio-to-Text Conversion

No.	Recording Duration	Processing Time
1.	1 min	14 secs
2.	2 mins	32 secs

Table 4 displays the speed at which audio is converted to text in English. The data reveals an average conversion time of 15.3 seconds per minute, indicating efficient processing by the speech recognition system.

Table 5. Speech Recognition Accuracy in English

No.	Recording Duration	Words Count in Recording	Number of Words Successfully Converted	Accuracy Rate
1.	1 min	96	96	100%
2.	2 mins	157	154	98.01%

Table 5 provides information on the accuracy of speech recognition in English. It presents data on the number of words in the recordings and the corresponding successfully transcribed words. The average accuracy rate of 99% demonstrates the system's ability to convert spoken words to written text in English accurately.

The personal assistant robot prototype has a 2-minute maximum duration for English audio recordings due to its primary programming focus on the Indonesian language. Nevertheless, it can still perform English speech recognition within this time constraint, offering an added advantage alongside its Indonesian language capabilities.

These findings demonstrate the prototype's satisfactory performance in converting English audio recordings into written text. Despite being primarily programmed for Indonesian, the system's ability to support English speech recognition, albeit with a limited timeframe, showcases its versatility. This adaptability enhances the robot's usability and ensures effective communication in both languages.

Figure 8. Documentation

The personal assistant robot prototype excels not only in audio-to-text conversion but also in visual documentation. As shown in Figure 8, the prototype captures high-quality photos at a resolution of 1280 x 720 pixels, ensuring clear and detailed images.

The photo is efficiently stored and readily accessible on Google Drive, offering users easy access and usability. This capability enhances the prototype's versatility, allowing users to document events, capture visual information, and seamlessly integrate visual content into their tasks.

The clarity and detail of the images significantly contribute to visual recognition tasks and provide valuable visual documentation for various applications.

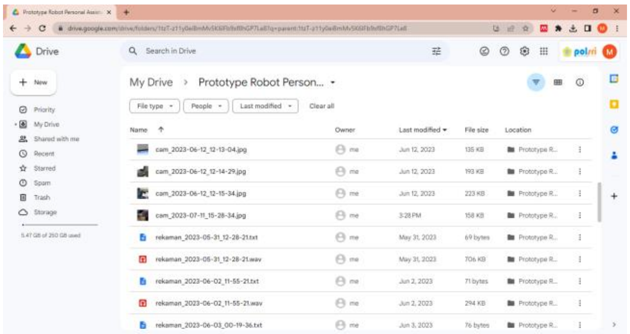

Figure 9. Google Drive

Figure 9 displays a screenshot of the Google Drive folder, which contains recorded files (.wav), converted transcripts (.txt), and captured images (.jpg) sent by the robot. The personal assistant robot prototype transfers audio, recordings, and text to Google Drive in real-time, with transfer times dependent on file size and internet connectivity.

Access to the Google Drive folder is restricted to the owner, ensuring data privacy and security. The owner can grant specific file access to others, enabling controlled and authorized sharing.

This integration with Google Drive enhances data management convenience, allowing users to access recorded content from any internet-connected device. Real-time transfer ensures immediate availability and preserves data integrity.

Secure and controlled access to the Google Drive folder protects sensitive information, empowering users to utilize and share their recorded content as desired confidently.

In summary, the integration with Google Drive provides a seamless and secure storage solution for audio, recordings, and text captured by personal assistant robots, offering users a reliable platform to manage and access their valuable data.

CONCLUSIONS

In conclusion, the personal assistant robot prototype excels in speech recognition and visual documentation. It achieves an impressive accuracy rate of 100% in Indonesian and 99% in English, exhibiting remarkable precision in converting audio recordings into written text. Additionally, the prototype showcases efficient processing speed, averaging 9.07 seconds per minute in Indonesian and 15.3 seconds per minute in English. Integrating a high-resolution webcam at 1280 x 720 pixels enhances its imaging capabilities. Real-time integration with Google Drive ensures secure and convenient storage, facilitating seamless data management and accessibility. Overall, the prototype's outstanding accuracy and efficient processing speed establish it as a reliable and effective personal assistant, particularly in meeting and collaborative work settings, enabling smooth interactions and effective communication.

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