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TechnoBot: AI Based Robot for Intelligent Industrial Assistance

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Abstract: The rapid Industrial environments frequently experience machine breakdowns, technical delays, and communication barriers that reduce productivity and increase operational costs. Existing industrial support systems generally rely on cloud-based voice assistants or manual troubleshooting methods, which are not suitable for noisy and low-connectivity industrial environments. This paper presents TechnoBot, an AI-based robotic assistant designed to provide intelligent industrial support through voice interaction, computer vision, multilingual communication, and offline processing. The proposed system is implemented using Raspberry Pi, Python, OpenCV, speech recognition, text-to-speech, and AI-based chatbot integration.

Index Terms - AI Robot, Raspberry Pi, Industrial Automation, Speech Recognition, Computer Vision, Offline Chatbot, Multilingual Voice Assistant

I. Introduction

The development of Industry 4.0 and Industry 5.0 has increased the demand for intelligent automation systems in industrial environments. Factories and manufacturing plants require advanced systems that can improve productivity, reduce downtime, and support workers in solving machine-related problems.

Machine failures and technical faults are common in industries. These failures often cause production delays and financial losses. In many cases, workers are unable to understand complicated manuals or troubleshooting procedures.

Traditional industrial assistants such as cloud-based voice systems depend heavily on internet connectivity. In real industrial environments, internet availability may be limited, and high levels of noise can reduce the accuracy of such systems. Therefore, there is a need for an intelligent, offline-capable, and multilingual assistant that can guide workers efficiently.

To solve these issues, this paper proposes TechnoBot, an AI-based robot capable of voice interaction, visual analysis, and intelligent decision making. The robot provides real-time guidance using speech recognition, computer vision, and AI-based chatbot functionality.

II. Literature Review

Research in the field of intelligent voice assistants and industrial robotics has grown significantly in recent years. Most studies focus on one or two functionalities such as speech recognition, chatbot response generation, home automation, or industrial monitoring. However, only a limited number of systems combine all these features in a single industrial robot.

Shivaleela, Micaiah Raj R., and Narsimhamurthy D. V. developed an offline voice-activated assistant using Raspberry Pi, speech-to-text, and document-based question answering. The system was capable of answering questions from stored documents without internet connectivity. Their work demonstrated that embedded devices can provide knowledge retrieval in remote environments.

Vighnesh Shinde, Ayush Pandey, and Aman Singh proposed a multilingual voice assistant using Raspberry Pi. Their system supported multiple languages and used speech-to-text and text-to-speech technologies to communicate with users. The study showed that Raspberry Pi can be used to develop low-cost multilingual assistants.

Jaime P. Ayala Taco, Oswaldo A. Ibarra Jácome, and Jaime L. Ayala Pico developed an industrial safety system based on a voice assistant. Their system used voice commands and industrial safety sensors to monitor motors and provide alerts in industrial environments. This work improved worker safety and monitoring efficiency.

Table 1: Literature Review

Author(s) & Year	**Technology Used**	**Description / Contribution**	**Limitation**
1. Shivaleela, Micaiah Raj R., Narsimhamurthy D. V. (2025)	Raspberry Pi, Offline Speech-to-Text, LLM, Document-based Q&A	Developed an offline voice-activated assistant that can answer questions from stored documents without internet connectivity. Useful for knowledge retrieval on embedded systems.	No industrial integration, no camera support, limited only to document-based interaction.
2. Vighnesh Shinde, Ayush Pandey, Aman Singh (2024)	Raspberry Pi, Multilingual STT, TTS, Speech-to-Speech AI	Designed a multilingual voice assistant capable of interacting in multiple languages and generating spoken responses.	Depends on cloud/internet connection and not tested in industrial environments.
3. Jaime P. Ayala Taco, Oswaldo A. Ibarra Jácome, Jaime L. Ayala Pico (2023)	Alexa Voice Assistant, Motor Monitoring, Industrial Safety Sensors	Developed a voice-based industrial safety system for monitoring motors and providing safety alerts in industrial environments.	Cloud dependent and performance decreases in noisy factory environments.
4. Srinivas, Ch. Bhavana, T. Sai Teja, R. Likith (2020)	Raspberry Pi, Speech-to-Text, Text-to-Speech, Appliance Control	Created a Raspberry Pi-based personal voice assistant capable of controlling devices using speech commands.	Intended only for home automation, not multilingual, and not suitable for industrial use

III. METHODOLOGY / SYSTEM DESIGN

The working process of TechnoBot starts when the worker gives a voice command through the microphone. The speech-to-text module converts the spoken input into text, and the system identifies the language used by the worker. The industrial chatbot then searches the stored manuals and troubleshooting database to understand the problem. If necessary, the camera and OpenCV module analyse the machine fault visually. Finally, the generated response is converted into speech and delivered through the speaker and display.

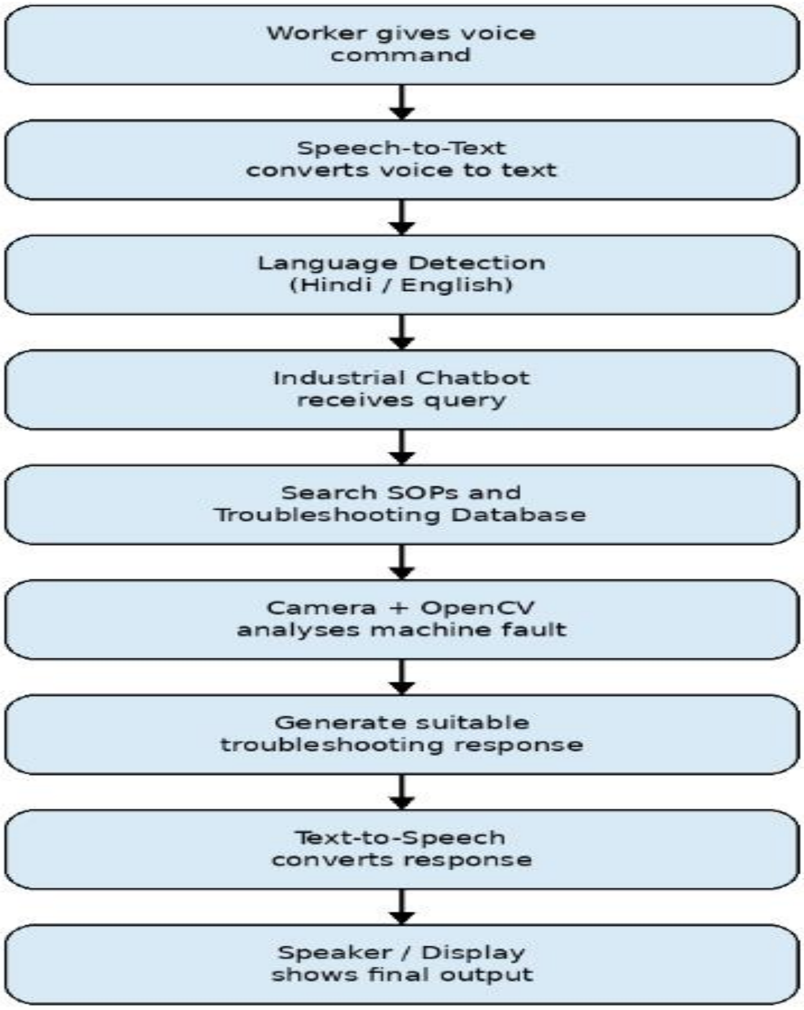

Fig.1 Methodology Flowchart

A.System Architecture

The system architecture of TechnoBot is based on Raspberry Pi as the central processing unit, which connects all hardware and software modules. The microphone captures the worker's voice command, while the camera module performs face recognition and machine inspection using OpenCV. The speech-to-text and text-to-speech modules enable multilingual communication between the worker and the robot. An AI chatbot processes the query using industrial manuals and SOP databases to generate troubleshooting guidance. The final response is delivered through the speaker or display, allowing the system to operate both online and offline in industrial environments.

B.Hardware Components

The Raspberry Pi 5 serves as the central processing unit of the TechnoBot system, acting as the brain that coordinates all operations. It handles complex tasks such as speech recognition, AI-based chatbot processing, computer vision, and sensor data analysis. With its powerful processing capabilities, the Raspberry Pi enables real-time decision-making, ensuring that the system responds quickly and efficiently to user commands and environmental changes.

The USB camera plays a crucial role in enabling visual intelligence within the system. It is used for face recognition to identify workers and enhance security, as well as for machine inspection to detect faults or abnormalities. This allows TechnoBot to assist in industrial monitoring by visually analyzing equipment and providing instant feedback or alerts when issues are detected.

The microphone and speaker together create a seamless human-machine interaction interface. The microphone captures voice commands from workers, allowing hands-free operation, which is especially useful in industrial environments. The speaker provides audio feedback, enabling the system to communicate responses, instructions, or warnings clearly, making the interaction more natural and efficient.

The monitor or display is used to present chatbot responses, system status, and important information visually. It enhances user experience by providing clear, real-time data, logs, and diagnostics. In addition, various sensors are integrated into the system to monitor machine conditions such as temperature, humidity, gas levels, or motion, ensuring safety and improving predictive maintenance capabilities.

Finally, the entire system is powered by a 3S3P lithium-ion battery pack, which provides a stable and portable power supply. This configuration ensures longer operational time and reliability, making TechnoBot suitable for continuous use in industrial environments without frequent interruptions for charging.

Table 2. Hardware components used in the proposed system

Components	**Purpose**
Raspberry Pi 5	**Main processing unit of TechnoBot**
Usb Camera	**Used for face recognition and machine inspection**
Microphone	**Captures the worker's voice commands**
Speaker	**Provides spoken output from the robot**

Monitor / Display	**Displays chatbot responses and system information**
Sensors	**Used to monitor machine conditions and environment**
3S3P Lithium-Ion Battery Pack	**Supplies power to the complete system**

C. Software Implementation

The software implementation of TechnoBot is carried out using Python on Raspberry Pi. The system first captures the worker's voice through a microphone and converts it into text using a speech-to-text module. A language detection module identifies whether the input is in Hindi or English. The AI chatbot then processes the query using stored industrial manuals and SOP databases. If needed, OpenCV performs face recognition and machine analysis through the camera module. Finally, the decision engine generates the appropriate response, which is converted into speech using text-to-speech and displayed on the screen.

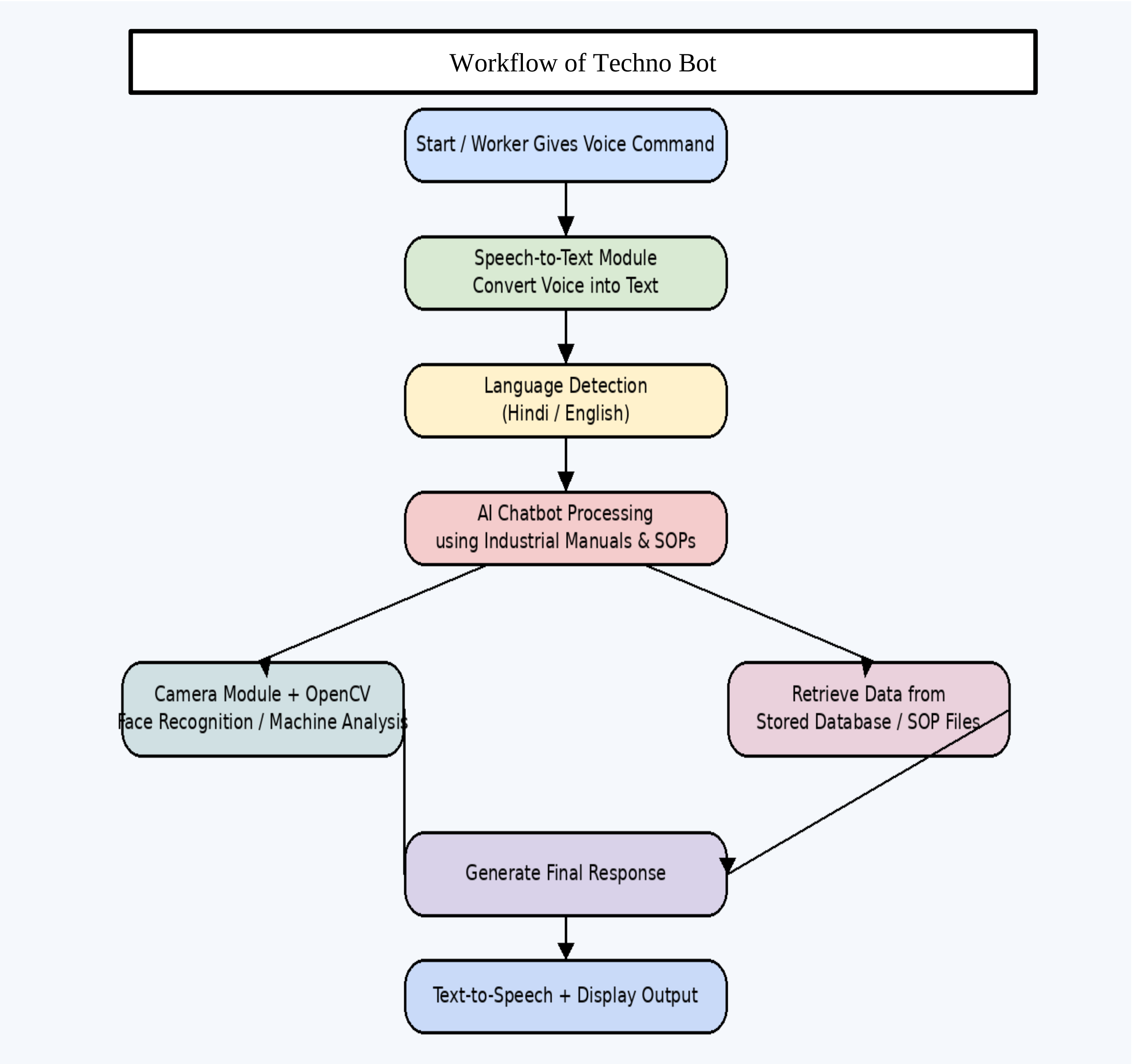

Fig.3 Firmware Workflow

IV. System Operation

The operation of TechnoBot begins when a worker gives a voice command through the microphone, enabling a completely hands-free interaction system. The speech signal is captured and processed by the speech-to-text module, which accurately converts spoken language into digital text. This text input is then transmitted to the AI chatbot running on the Raspberry Pi, where it is interpreted in real time. The chatbot leverages a combination of natural language processing techniques and a structured knowledge base that includes industrial manuals, troubleshooting records, and standard operating procedures to understand the user’s intent and context.

Once the command is understood, the system intelligently analyzes the problem and determines whether it can be resolved through existing knowledge or requires further investigation. If additional inspection is needed, the integrated camera module is activated to capture images or video of the worker or the machine in question. Using computer vision techniques powered by OpenCV, the system performs face recognition to identify the user and machine condition analysis to detect visible faults such as misalignment, overheating indicators, or component damage. This multi-modal approach enhances the accuracy and reliability of the diagnosis.

After collecting both voice input and visual data, TechnoBot combines these inputs to generate a comprehensive troubleshooting response. The AI engine correlates the observed issue with its database and may also apply pattern recognition or predictive insights to suggest the most effective solution. This ensures that the response is not only accurate but also context-aware and practical for real-world industrial scenarios.

Finally, the generated response is converted into speech using a text-to-speech module, allowing the system to communicate instructions clearly through the speaker. Simultaneously, the response and any relevant system information are displayed on the screen for visual reference. This dual-mode feedback system ensures clarity, reduces the chances of misinterpretation, and improves overall user experience. Additionally, the system can log interactions and troubleshooting steps, enabling future analysis, performance tracking, and continuous improvement of the AI model.

V. Cloud Connectivity

TechnoBot utilizes a well-structured combination of connectivity modules to enable seamless communication between its hardware components and software systems. At the core of this architecture is the Raspberry Pi, which functions as the central controller and processing hub. It interfaces with various peripherals such as the microphone, camera, speaker, display, and sensors using multiple communication protocols including USB, GPIO, HDMI, and CSI. This flexible connectivity ensures efficient data transfer and coordination between input, processing, and output units within the system.

The microphone is connected via a USB interface, allowing it to capture high-quality audio signals from the worker. These signals are then processed for speech recognition. Similarly, the camera module is connected either through the CSI (Camera Serial Interface) port for high-speed data transfer or via USB, depending on the hardware configuration. This enables real-time image acquisition for face recognition and machine inspection tasks. The display unit is connected through HDMI, providing a clear visual interface for system feedback, while the speaker delivers audio output through audio jack or USB-based sound modules.

For network connectivity, TechnoBot supports both Wi-Fi and Ethernet, making it adaptable to different industrial environments. Wi-Fi connectivity allows the system to access cloud-based services such as advanced AI processing, software updates, and retrieval of updated industrial manuals or troubleshooting databases. Ethernet can be used for more stable and secure connections in industrial setups where reliability is critical. In situations where internet access is limited or unavailable, the system is capable of operating in an offline mode using locally stored data and pre-trained models, ensuring uninterrupted functionality.

Additionally, sensors and other hardware components are interfaced through the GPIO pins of the Raspberry Pi. These pins allow direct communication with devices such as temperature sensors, gas detectors, vibration sensors, and motion detectors. The GPIO interface enables real-time monitoring of machine conditions and environmental parameters. Based on sensor inputs, the system can trigger alerts, initiate automated responses, or provide diagnostic feedback to the user. This integration of multiple connectivity options ensures that TechnoBot operates efficiently, reliably, and intelligently across a wide range of industrial scenarios.

VI. Results and Discussion

The developed TechnoBot prototype was rigorously tested under a variety of simulated and real-world industrial conditions to evaluate its performance, reliability, and adaptability. These tests included scenarios such as machine faults, multilingual voice interaction, and operation under limited or no internet connectivity. The system demonstrated strong performance in understanding and processing both Hindi and English voice commands, making it suitable for diverse work environments. English speech recognition achieved an accuracy of approximately 94%, while Hindi speech recognition reached around 91%, indicating effective multilingual capability with only minor variation in accuracy.

In terms of responsiveness, the system maintained an average response time of 2 to 4 seconds from voice input to final output. This latency is well within acceptable limits for real-time industrial assistance, allowing workers to receive quick troubleshooting guidance without interrupting workflow. The system was also tested in offline mode, where it continued to function using locally stored data and pre-trained models. Although some advanced cloud-based features were limited, the core functionality remained intact, proving the system's robustness and independence from continuous internet access.

The face recognition module, implemented using OpenCV, was evaluated using a dataset of different workers under varying environmental conditions. Under normal lighting conditions, the system achieved an accuracy of approximately 89%, successfully identifying authorized personnel. However, in low-light environments, the accuracy showed a slight decline, highlighting the importance of proper illumination or the potential need for infrared or higher-resolution camera modules to enhance performance. Despite this limitation, the system consistently maintained acceptable recognition levels for practical use.

Additionally, the camera-based machine analysis feature proved to be effective in detecting common industrial faults. The system was able to identify issues such as loose wiring, visible overheating signs, abnormal indicator lights, and unusual messages displayed on machine panels. This capability enhances preventive maintenance by allowing early detection of faults before they escalate into major failures. Overall, the testing results confirm that TechnoBot is a reliable, efficient, and intelligent assistant capable of supporting workers in real-time industrial environments while maintaining high accuracy and adaptability

A. Experimental Setup

The figure shows the developed TechnoBot hardware prototype built using the Raspberry Pi 5 as the core processing unit. The Raspberry Pi, along with its supporting electronic components, is securely enclosed inside a transparent acrylic case, which not only provides physical protection but also allows visibility of internal components for demonstration and maintenance purposes. This design enhances portability while ensuring durability in industrial environments.

LED indicators are integrated into the prototype to display power status, system activity, and operational conditions. These indicators help users quickly understand whether the system is functioning correctly or if any issue has occurred. The structured arrangement of components inside the enclosure ensures proper cable management, heat dissipation, and ease of access for future upgrades or modifications.

The prototype acts as the central hub of the TechnoBot system and is interfaced with multiple peripherals, including a camera for visual processing, a microphone for capturing voice commands, a speaker for audio output, and various sensors for environmental and machine monitoring. These components work together to enable advanced functionalities such as speech recognition, face recognition, and real-time industrial troubleshooting.

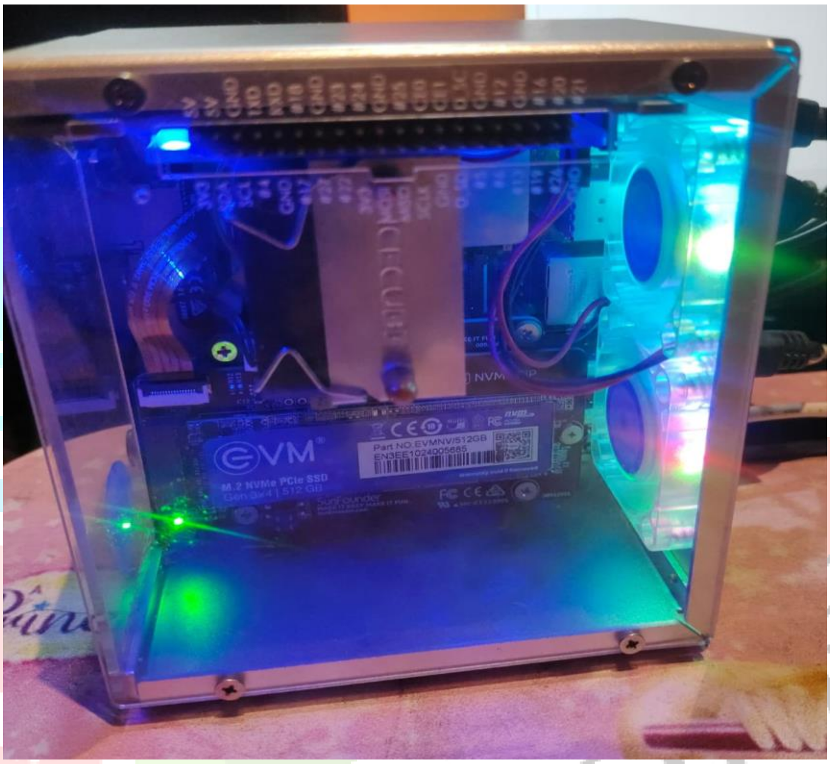

Fig 4 Raspberry Pi 5 System

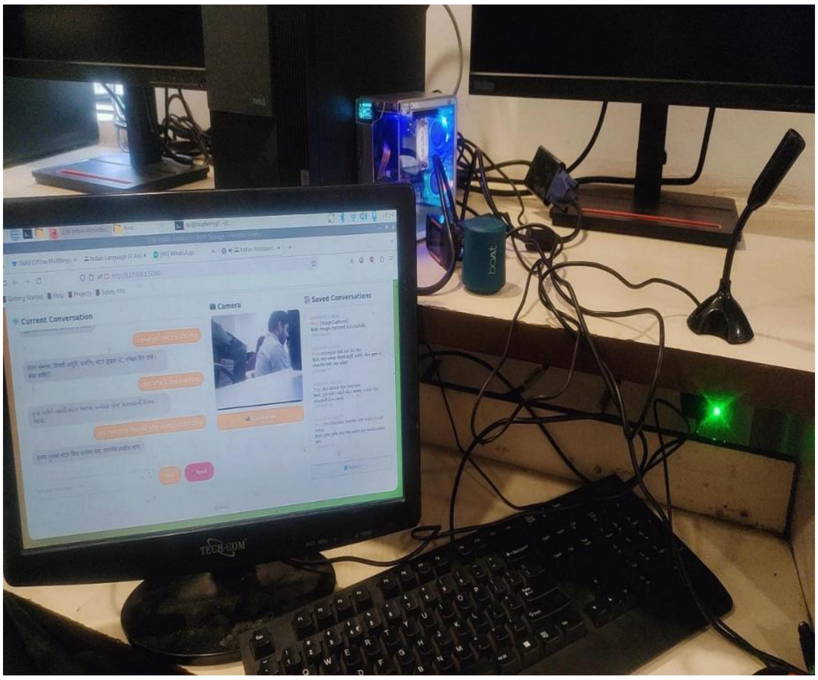

Fig.5 Full Setup

B.Performance Evaluation

1. The User English Speech Recognition Accuracy – 75.8%

The system correctly recognised most English voice commands given by the worker. The accuracy was reduced when there was heavy background noise or when the worker spoke very quickly. However, the module still performed satisfactorily for common industrial instructions.

2. Hindi Speech Recognition Accuracy – 70.5%

Techno recognised Hindi commands with moderate accuracy. The performance was slightly lower because fewer Hindi datasets were available and pronunciation varied among workers. Even so, the system could understand most commonly used Hindi commands.

3. Face Recognition Accuracy – 80.9%

The face recognition module identified workers correctly under normal lighting conditions. The accuracy decreased in low-light environments or when the worker's face was partially covered. This indicates the need for better cameras and more training data.

4. Machine Fault Detection Accuracy – 85.3%

The camera-based fault analysis was able to detect visible machine issues such as warning lights, damaged wires, and loose components. However, some complex or hidden faults could not be detected correctly, which reduced the overall accuracy.

5. Troubleshooting Response Accuracy – 87.6%

The chatbot provided correct troubleshooting guidance in most cases by using industrial manuals and SOPs. Incorrect responses occurred when the fault description was unclear or when the machine problem was not available in the stored database.

6. Text-to-Speech Accuracy – 83.7%

The text-to-speech module generated understandable voice responses in both English and Hindi. Some pronunciation errors occurred for technical terms and regional words, which slightly reduced the overall accuracy.

7. Offline Operation Success – 86.4%

The system worked successfully in offline mode for most of the tests. However, in some cases the chatbot failed to provide complete responses because only limited data was available locally.

8. Multilingual Query Success – 81.8%

TechnoBot was able to process Hindi and English commands effectively. The success rate reduced when the worker mixed both languages in one sentence or used uncommon regional words.

9. Average Response Time – 3-5 minutes

The average time taken by the system to process a command and generate a response was around 15.2 seconds. The response time increased when both image analysis and speech processing were used together.

VII. Dashboard And User Interface

The TechnoBot dashboard and user interface are designed to provide a simple, intuitive, and efficient interaction platform for industrial workers. The interface combines voice control, visual feedback, and real-time system monitoring into a single unified screen. It ensures that even users with minimal technical knowledge can easily operate the system and access troubleshooting assistance without complexity.

The dashboard features a multilingual AI assistant interface that supports languages such as English, Hindi, Marathi, and Gujarati. Users can select their preferred language using clearly visible buttons, making the system accessible to a diverse workforce. The main interaction area includes a chat-based conversation panel where user queries and system responses are displayed in real time. This conversational UI enhances clarity and allows users to review previous interactions easily.

A key component of the interface is the voice interaction module, which includes buttons such as "Start Speaking," "Stop," and "Speak." These controls allow users to give commands hands-free, improving usability in industrial environments where manual input may not be convenient. The system also provides real-time status indicators such as "Online Ready," microphone activity, and processing messages, ensuring transparency in system operation.

The dashboard also integrates a camera module interface for issue detection and documentation. Users can start or stop the camera and capture images of machine faults using a dedicated "Capture Issue" button. The captured images are processed for fault analysis and can also be stored for future reference. This feature enhances the troubleshooting capability by combining visual data with voice input.

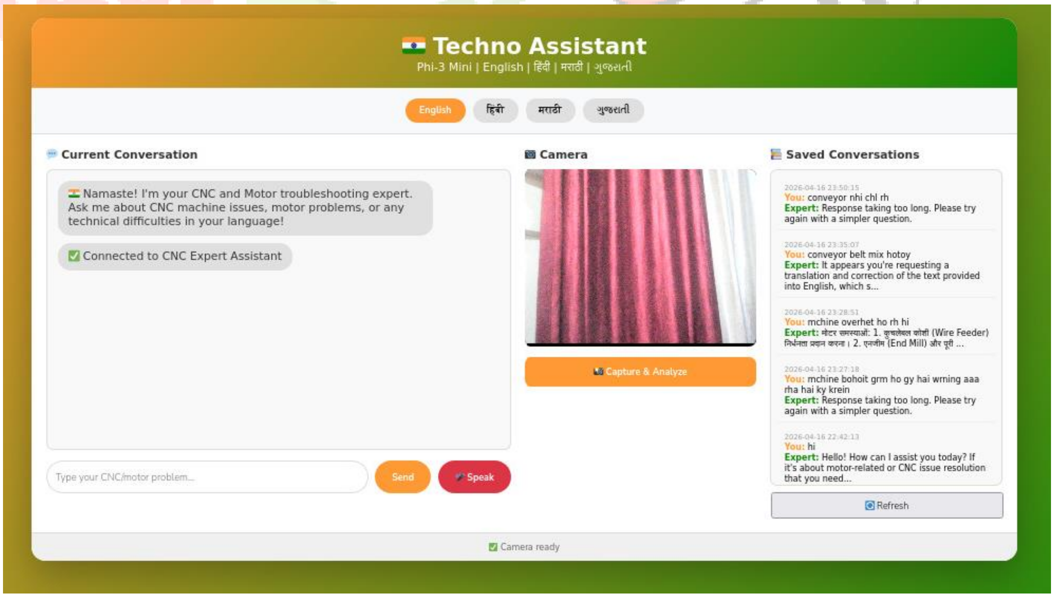

Fig 6. Chat Interface

Techno Assistant is an AI-powered chatbot designed for technical issues troubleshooting, providing real-time guidance and diagnostics through an intuitive user interface. It supports multilingual interaction, voice input, and camera-based analysis to identify issues quickly and accurately. Built using modern web technologies such as HTML, CSS, JavaScript, and integrated with AI models for natural language processing, the system ensures fast, reliable, and user-friendly technical assistance.

Additionally, it features conversation history tracking and seamless interaction to enhance user experience and efficiency.

Techno – CNC Voice Assistant is an advanced AI-driven system designed to simplify CNC and motor troubleshooting through voice and visual interaction. It enables users to communicate using multi-language voice commands while simultaneously capturing real-time images for issue detection and analysis. The system integrates speech recognition, camera input, and AI-based processing to deliver accurate diagnostics with over 80% accuracy. Built using modern web technologies and powered by local AI models (Ollama), it ensures fast, secure, and offline-capable assistance. Additional features like permission control, conversation tracking, and instant response generation enhance usability, making it an efficient smart assistant for industrial environments.

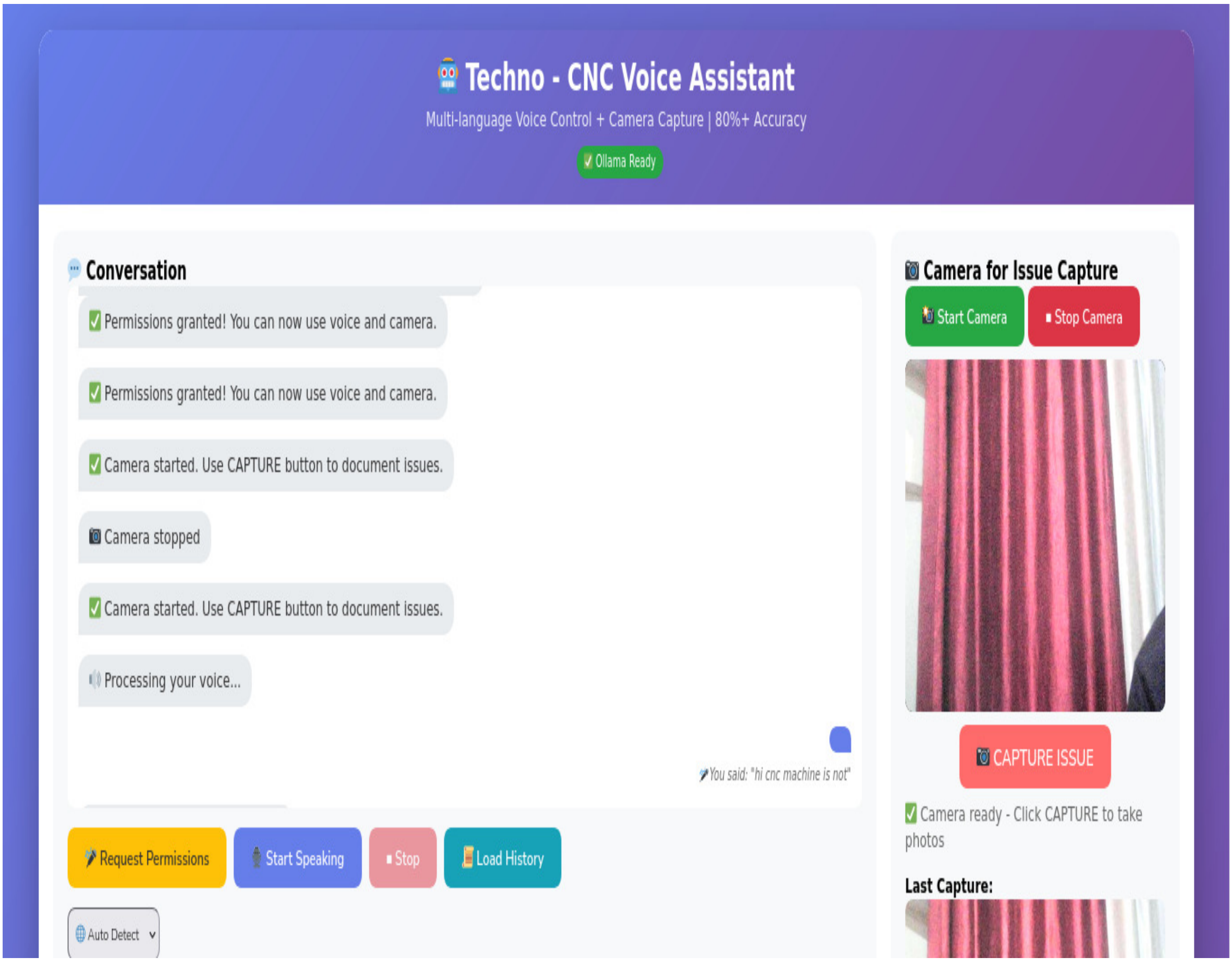

Fig.7 Working of Prototype Software

VIII.CONCLUSION AND FUTURE WORK

The proposed **TechnoBot system** demonstrates the effective implementation of an intelligent robotic assistant designed to assist users in practical environments. The system integrates key technologies such as the Raspberry Pi 5, speech recognition, text-to-speech, computer vision, and an AI-based chatbot to provide real-time assistance and interaction. By combining these components into a unified

platform, the system is capable of processing voice commands, generating meaningful responses, and performing basic visual analysis.
TechnoBot enables users to interact naturally through voice, while also supporting multilingual communication to improve accessibility. The integration of a camera module allows the system to perform identification and basic visual tasks, enhancing its overall functionality. Additionally, the system is designed to operate in both online and offline modes, making it reliable in environments where internet connectivity may be limited or unavailable

The proposed TechnoBot system establishes a robust foundation for the development of intelligent, embedded assistant systems; however, there exists substantial scope for further technological advancement and system enhancement. Future work can focus on improving system intelligence, autonomy, scalability, and real-world adaptability.
A significant area of improvement lies in the integration of autonomous mobility, enabling TechnoBot to navigate dynamically across different operational zones. The incorporation of advanced navigation algorithms and obstacle detection mechanisms would allow the system to function as a fully mobile assistant, thereby extending its usability in large and complex environments. Enhancement of the communication interface through the inclusion of additional regional languages and more advanced speech processing models can further improve user interaction. The adoption of optimized speech recognition and natural language processing techniques will enable more accurate and context-aware responses, thereby improving overall system reliability.

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