KITCHAI - ENHANCING CULINARY INDEPENDENCE FOR THE VISUALLY IMPAIRED

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Introduction:

In modern kitchens, ensuring safety and accessibility for visually impaired individuals is a critical challenge due to the presence of potential hazards like open flames, hot surfaces, gas leaks, and sharp objects. Traditional kitchen setups are not designed to cater to the needs of users with visual impairments, often making them dependent on others. With the advancement of embedded systems, artificial intelligence, and IoT, there is an opportunity to redesign everyday appliances and environments to be inclusive. This project aims to address this gap by creating a smart kitchen assistant that uses a combination of AI and IoT technologies to assist visually impaired users in navigating, cooking, and handling common kitchen tasks independently. The system includes sensors for gas, fire, temperature, and weight; a camera module for object detection; OCR for label reading; and a voice feedback module to provide real-time instructions and alerts. The primary focus is safety, ease of use, and independence in daily cooking activities. By providing timely warnings and guidance through voice alerts, the system aims to reduce accidents and boost confidence for the users. This solution bridges the accessibility gap in home automation through a practical, scalable, and user-centered approach.

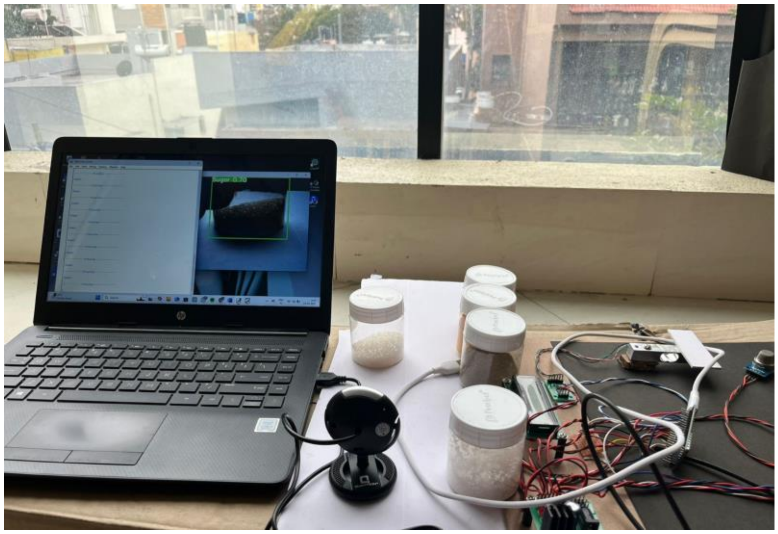

Fig 1: KitchAI project setup

Objectives:

- Develop an intelligent kitchen assistant tailored for visually impaired users.
- Integrate gas, fire, and temperature sensors to monitor environmental safety.
- Enable object detection using YOLOv5 to recognize common kitchen tools and ingredients.
- Use Tesseract OCR for reading labels and providing voice-based content.
- Implement a load cell-based inventory tracking system.
- Offer real-time voice feedback using text-to-speech technology.
- Create a centralized microcontroller-based platform with ESP32.
- Design the system to be affordable, modular, and scalable for household use.

Methodology:

The proposed system integrates multiple modules—sensing, processing, and feedback—into a unified smart kitchen assistant. At the core of the system lies an ESP32 microcontroller that serves as the central processor, coordinating input from various sensors. Gas sensors (MQ-series) detect leakage and trigger an automatic servo to close the gas valve. Fire and temperature sensors continuously monitor for dangerous conditions, triggering alerts and protective actions such as buzzers. Load cells paired with HX711 modules track ingredient weights, ensuring inventory management. A camera module captures real-time visuals of the kitchen workspace. These images are processed using the YOLOv5 object detection model trained on common kitchen tools and ingredients. The software side is developed using Python and MicroPython. Tesseract OCR is used to recognize text from food labels and packaging. The ESP32 processes the OCR and object detection results and delivers spoken output through the pyttsx3 TTS engine, ensuring real-time, accessible feedback. All modules are connected via GPIO and I2C interfaces to the ESP32 and are powered through a regulated 5V supply. The components are mounted on a structured prototype board, and the system is enclosed in a safe casing to replicate a kitchen setting. Testing was done in stages, from individual component validation to full system integration, ensuring robustness and safety.

Result and Conclusion:

The final prototype successfully demonstrated the core objectives. Gas leaks were detected with an average latency of 2 seconds, and the servo response to shut the gas supply was immediate. Fire detection triggered alerts within 1.5 seconds during trials. The load cell accurately detected changes in ingredient weight with ±5g precision. The YOLOv5 model achieved over 90% accuracy in recognizing kitchen items. OCR correctly identified printed labels in various fonts with 85-90% reliability. Real-time voice prompts were generated successfully in both English and regional languages. During user simulation, the system provided timely alerts and guided the user through cooking tasks. Photographs and sensor data were logged for validation. Charts displaying the sensor response times and detection accuracies confirmed the system's reliability. Overall, the prototype improved safety, enhanced independence, and proved viable for domestic assistive applications in smart kitchens.

Project Outcome & Industry Relevance:

The developed system serves as a prototype for smart kitchen solutions tailored to accessibility. The successful integration of AI and IoT showcases its industry relevance in smart home automation and elder care. With rising interest in inclusive technology, the system aligns well with current demands. It provides real-world applications in home safety, assistive appliances, and autonomous monitoring systems. The modular design also opens doors for commercial appliance manufacturers to integrate similar features. The experience contributes to innovations in embedded systems and inclusive design engineering.

Working Model vs. Simulation/Study:

This project was implemented as a working model. All sensors, processing units, and feedback systems were integrated and demonstrated successfully. Testing was done in a real kitchen simulation environment.

Project Outcomes and Learnings:

The students learned about sensor integration, microcontroller programming, machine learning deployment, and accessibility-driven design. Hands-on experience in integrating hardware and software in a safety-critical application added valuable practical knowledge.

Future Scope:

The system can be further enhanced by integrating it with mobile applications to allow caregivers to monitor users remotely. Cloud integration can enable real-time logging and alerting for anomaly detection. Incorporating advanced natural language processing would allow users to interact more naturally with the system. The object detection database can be expanded to include a wider range of items including perishables. Automated cooking processes and robotic arms can be introduced in future iterations. Machine learning models can be fine-tuned using reinforcement learning based on user interaction. Energy optimization for longer runtime can be considered. Voice assistance in multiple regional languages will enhance user experience. Health monitoring extensions can help track dietary intake and suggest personalized recipes. Long-term usability testing will help refine the interface and deployment strategy.