IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Smart Lab Assistant Library

Subha Bharvani[1], Sakshi Dhope[2], Shweta Kapashi[3], Md Tahirim Mulla[4], Md Ayyan Mulla[5]

[1]UG student, Department of Electronic and Communication , Maratha Mandal's Engineering College, Belagavi

[2]Associate Professor, Department of Robotics & AI, Maratha Mandal's Engineering College, Belagavi

Abstract

Laboratory environments require strict safety and efficient information access systems to prevent accidents and improve productivity. One of the major risks in laboratories is undetected gas leakage, which can lead to severe health hazards and potential explosions. Additionally, the unavailability of quick access to essential laboratory information often causes delays and errors during experiments. To address these issues, this research presents a **Smart Laboratory Safety and Information System** integrating **gas leak detection** and **AI-based information retrieval**. The system employs a gas sensor to detect harmful gases in real time and uses **Blynk Cloud** to send instant alerts to mobile devices, ensuring immediate response and safety. For efficient information management, an **AI chatbot** powered by the **OpenAI API** is implemented using Python, enabling lab personnel to instantly retrieve data such as equipment details, safety protocols, and experiment procedures. This dual approach enhances both safety and operational efficiency within laboratory settings. The proposed system demonstrates how the integration of **IoT** and **AI technologies** can create a smarter, safer, and more responsive laboratory environment.

Keywords: Gas Leak Detection, Laboratory Safety, IoT, Blynk Cloud, OpenAI API, AI Chatbot, Smart Lab, Information Retrieval.

1. Introduction

Laboratories are essential environments for research, experimentation, and innovation; however, they also pose significant safety risks if proper monitoring and control systems are not maintained. Among these risks, **gas leakage** is one of the most critical hazards, as even a small undetected leak can lead to serious health problems such as dizziness, nausea, or suffocation, and in severe cases, cause fires or explosions. Ensuring early detection and quick response to such incidents is vital to protect both human life and valuable laboratory infrastructure.

Apart from safety, **instant access to laboratory information** is equally important for smooth operations. Laboratory staff often face challenges in quickly retrieving important details such as equipment manuals, chemical handling procedures, or safety protocols. This delay can slow down experiments, increase the likelihood of procedural errors, and reduce overall productivity. The absence of an efficient information access system not only affects workflow but can also compromise safety during critical situations.

To address these challenges, this research focuses on developing a **Smart Laboratory Safety and Information System** that combines **gas leak detection** with **AI-based information retrieval**. The system utilizes a gas sensor for real-time monitoring of hazardous gases, connected to the **Blynk Cloud** platform, which provides instant alerts on mobile devices whenever abnormal gas levels are detected. Simultaneously, an **AI chatbot**, powered by the **OpenAI API** and developed using **Python**, serves as an intelligent assistant to help laboratory personnel instantly access essential information.

The primary objective of this research is to create a **safe, responsive, and intelligent laboratory environment** by integrating **Internet of Things (IoT)** technology with **Artificial Intelligence (AI)**. This combined approach not only enhances safety through immediate detection and alert mechanisms but also improves efficiency by providing quick access to vital information, thus contributing to a smarter and more reliable laboratory system.

2. Methodology

Hardware (Gas Detection Module)

1. **Gas Sensors:**
   - MQ-series sensors (e.g., MQ-2, MQ-5) used for detecting combustible and toxic gases.
   - Provide analog voltage proportional to gas concentration.
2. **Microcontroller / IoT Board:**
   - ESP32 / ESP8266 microcontroller for ADC sampling and Wi-Fi communication.
   - Sends processed sensor data to the Blynk Cloud or local database.
3. **Signal Conditioning:**
   - Includes smoothing capacitors, pull-down resistors, and optional operational amplifiers.
   - Ensures stable and accurate sensor readings.
4. **Local Alert Hardware:**
   - Components such as buzzers, LEDs, or relays are used to trigger local alarms.
   - Relay can close gas valves or activate ventilation during emergencies.
5. **Power and Protection:**
   - Uses UPS or battery backup for uninterrupted operation.
   - Includes fuses and surge protection to safeguard electronic components.
6. **Cloud Connectivity:**
   - Blynk Cloud for IoT-based data logging and mobile push notifications.
   - Optional SMS gateway for escalation during critical events.

Software (Information Retrieval Module)

1. **Edge / Host Device:**
   - Raspberry Pi (or alternative cloud VM) hosts the Python backend.
2. **Backend Framework:**
   - Developed using Flask or FastAPI for efficient API endpoints and chatbot services.
3. **Retriever / Vector Database:**
   - SQLite integrated with FAISS (or similar) to store document embeddings for manuals, SOPs, and experiment procedures.
4. **OpenAI API:**
   - Utilized for natural-language question answering and summarization.
   - Provides contextual, accurate responses using embeddings and similarity search.
5. **Mobile UI / Dashboard:**
   - Blynk mobile app or a web-based dashboard used for:
     - Viewing sensor readings
     - Receiving alerts
     - Accessing chatbot interface
6. **Logging and Audit System:**
   - Records sensor data, alerts, chatbot queries, and responses with timestamps for audit and traceability.

Integration & Safety Logic (Design Principles)

1. **Thresholding and Debounce:**
   - Uses time-window averaging and continuous exceedance validation to avoid false alerts.
2. **Multi-Level Alerting:**
   - **Warning Level:**
     - Sends push notification to mobile and updates dashboard.
   - **Critical Level:**
     - Triggers continuous buzzer and LED.
     - Sends push + SMS notification.
     - Activates relay to close valves or start exhaust systems.
     - Escalates to administrator.
3. **Automated Chatbot Responses:**
   - During alerts, chatbot provides instant SOPs and emergency instructions (e.g., evacuation steps, valve locations).

4. **Fail-Safe Mode:**
   - If cloud or network connection fails, microcontroller independently activates local alarms and stores data locally until reconnection.
5. **Role-Based Access:**
   - Sensitive documents and SOPs restricted to authorized personnel for data security.

Step-by-Step System Flow

Gas Detection Module Flow

1. **Sensing:** Gas sensor generates analog signal based on gas concentration.
2. **ADC Sampling:** ESP32 reads analog data periodically (every 1–5 seconds).
3. **Signal Processing:**
   - Applies calibration and smoothing to convert readings to ppm or relative units.
4. **Threshold Comparison:**
   - Below Warning Threshold: Log reading and continue monitoring.
   - **Warning Level:** Send push alert via Blynk; short buzzer beep; show dashboard alert.
   - **Critical Level:** Trigger continuous buzzer, push + SMS, activate relay (close valve/ventilate), log event.
5. **Debounce Logic:** Confirms high reading with N consecutive samples**.**
6. **Data Storage:** Logs readings and metadata (timestamp, ID, location).
7. **Post-Event:** Store event snapshot for post-incident review.

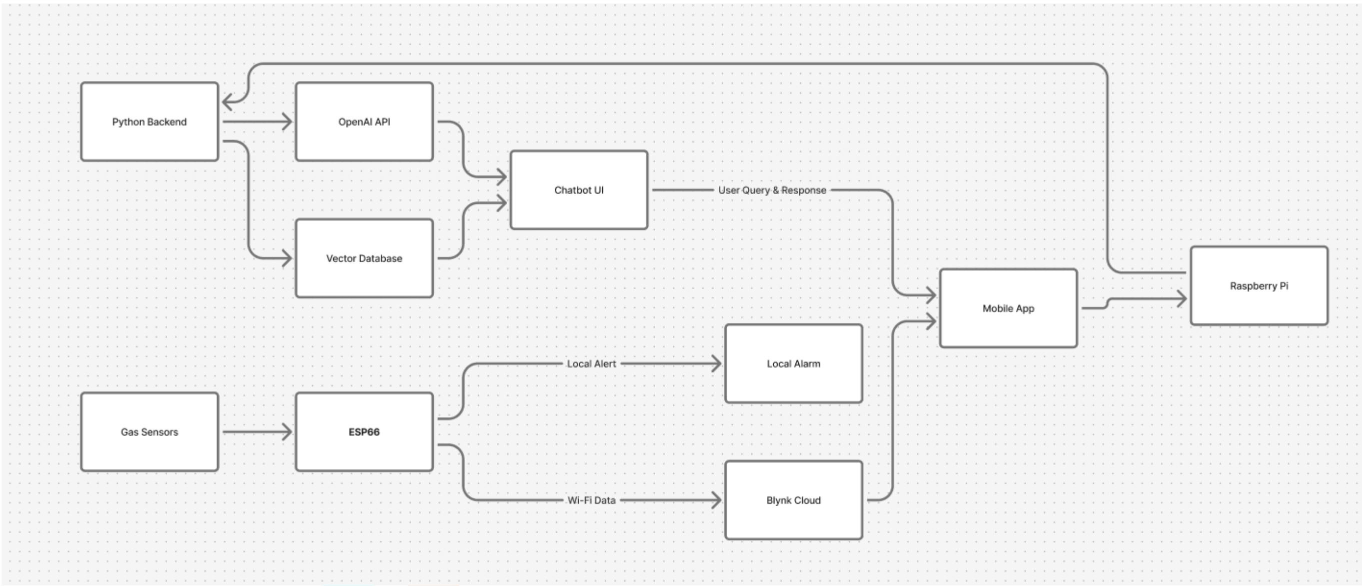
AI Chatbot Module Flow

1. **User Action:** User opens app/dashboard and sends a natural-language query.
2. **Frontend to Backend:** Query sent via API to Python backend.
3. **Embedding & Retrieval:** Backend encodes query and searches vector DB for relevant documents.
4. **Context Assembly:** Combines retrieved content with system prompt and sensor data (if alert-based query).
5. **OpenAI API Call:** Sends context to OpenAI for answer generation.
6. **Post-Processing:** Adds citations, SOP links, and formats the response.
7. **Response Display:** Answer shown in Chatbot UI; logs query-response pair with metadata.

Integrated (Alert → Assistance) Flow

1. **Detection:** Gas module detects critical gas concentration.
2. **Notification:** ESP32 sends alert → Blynk Cloud → Mobile App; event logged on server.
3. **Auto-Message:** Server sends pre-configured safety message through chatbot and notifications.
4. **User Interaction:**
   - User taps notification → opens chatbot UI with live data and instructions (e.g., “Evacuate”, “Shut Main Valve”).
5. **Escalation:**
   - If no acknowledgment within timeout, system escalates to admin via SMS/call.
6. **Post-Event:**
   - Stores logs and chat transcripts for report generation and safety audits.

Flow Diagram:



Calibration, Testing & Validation

1. **Sensor Baseline Calibration:**
   - Measure clean-air output to determine baseline (R_0).
2. **Calibration Curve Development:**
   - Use known gas samples or manufacturer data to map sensor response to gas concentration.
3. **Threshold Tuning:**
   - Set warning and critical thresholds based on safety standards and lab conditions.
4. **False Positive Testing:**
   - Conduct controlled tests under different temperature/humidity to refine debounce and smoothing.
5. **Integration Testing:**
   - Validate complete system pipeline:
     Sensor → ESP32 → Blynk → Mobile → Raspberry Pi → Backend → Chatbot.
6. **User Acceptance Testing (UAT):**
   - Engage lab personnel to test system usability, alert handling, and chatbot accuracy.
   - Collect feedback for retriever and system tuning.

References

1. Jordi Palacín, David Martínez, Eduard Closet, Tomàs Pallejà, Javier Burgués, Jordi Fonollosa, Antonio Pardo and Santiago Marco. "Application of an Array of MetalOxide Semiconductor Gas Sensors in an Assistant Personal Robot for Early Gas Leak
2. Ramon Barber, Miguel A. Rodriguez-Conejo, Juan Melendez and Santiago Garrido. "Design of an Infrared Imaging System for Robotic Inspection of Gas Leaks in Industrial Environments". International Journal of Advanced Robotic Systems.
   Received 28 July 2014; Accepted 15 December 2014, DOI: 10.5772/60058.
3. Vamsi B, Karthik H B, Mahantesh Navi, Bhanuteja G, Vidyasagar K N. "Advancements in Intelligent Robotics: Exploring Facial Recognition Technologies for Human Machine Interaction". 2023 Fourth International Conference on Smart
   Technologies in Computing, Electrical and Electronics (ICSTCEE) | 979-8-35038462-8/23/$31.00 ©2023 IEEE | DOI: 10.1109/ICSTCEE60504.2023.10584914.
4. Elena Torta, Johannes Oberzaucher, Franz Werner, Raymond H. Cuijpers, James F. Juola. "Attitudes Towards Socially Assistive Robots in in telligent Homes: Results from Laboratory Studies and Field Trials. Journal of Human-Robot Interaction, Vol. 1, No. 2, 2012, Pages 76-99. DOI 10.5898/JHRI.1.2.Torta.
5. Ashish Tarun, R., et al. "Leveraging LangChain Framework and Large Language Models for Conversational Chatbot Development." *International Research Conference on Computing Technologies*

for Sustainable Development. Cham: Springer Nature Switzerland, 2024.
Kourosh Darvish, Marta Skreta, Yuchi Zhao, Naruki Yoshikawa, Sagnik Som, Miroslav Bogdanovic, Yang Cao, Han Hao, Haoping Xu, Ala ´n Aspuru-Guzik, Animesh Garg, and Florian Shkurti. "ORGANA: A robotic assistant for automated chemistry experimentation and characterization". 2025, Matter 8, 101897 February 5, 2025 ª 2024 Elsevier Inc.

6. Gyeong-Geon Lee, Minji Choi, Taesoo An, Seonyeong Mun, Hun-Gi Hong. "Development of the Hands-free AI Speaker System Supporting Hands-on Science Laboratory Class: A Rapid Prototyping". Article in International Journal of Emerging Technologies in Learning (iJET) · January 2023 DOI: 10.3991/ijet. v18i01.34843.
7. M. Poongothai, K. Sundar, B. Vinayak Prabhu. "Implementation of IoT based Intelligent Voice Controlled Laboratory using Google Assistant". International Journal of Computer Applications (0975 – 8887) Volume 182 – No. 16, September 2018.
8. Zhao Gong, Songwen Jiang, Qizhi Meng, Yanlei Ye1, Peng Li1, Fugui Xie, Huichan Zhao, Chunzhe L, Xiaojie Wang4 and Xinjun Liu. "SHUYU Robot: An Automatic Rapid Temperature Screening System". Chinese Journal of Mechanical Engineering (2020).
9. Russell Stewart, Mykhaylo Andriluka, and Andrew Y. Ng. "End-to-end people detection in crowded scenes". Published in IEEE Xplore.
10. Julia Cambre, Ying Liu, Rebecca E. Taylor, Chinmay Kulkarni. "Vitro: Designing a Voice Assistant for the Scientific Lab Workplace". DIS '19, June 23–28, 2019, San
Diego, CA, USA.