Faktor Exacta
Vol. 17, No. 3, Sept 2024, pp. 241~250
eISSN: 2502-339X, pISSN: 1979-276X, DOI: 10.30998/faktorexacta.v17i3.21920

LPG Leak Detection System and LPG Fire Classification Based on Internet of Things and Artificial Intelligence with Telegram Bot as a Monitoring Tool

Dhimaz Purnama Adjhi[1], Mohamad Rizal Hanafi[2], Wirmanto Suteddy[3]
[1,2,3]Department of Computer Engineering, Universitas Pendidikan Indonesia, Indonesia

Article Info

Article history:

Received 6 Jan 2024
Revised 25 Jul 2024
Accepted 13 Aug 2024

Keywords:

LPG Leak Detection
LPG Fire Classification
Internet of Things
Artificial Intelligence
ESP32

ABSTRACT

LPG leaks pose a serious threat in industrial kitchens as they can cause costly fires, both in terms of material and safety. In order to improve safety, an accurate detection system is needed. This research develops a gas leak detection system and fire classification with Internet of Things technology and Artificial Intelligence. Supported by Telegram Bot as an emergency notification monitoring tool, this system uses the MQ-2 sensor to detect LPG leaks and ESP32-Cam as input to classify LPG fires using a Pretrained-model such as Cascade Fire Detection in OpenCV. System testing is done by Black-Box testing, then the performance is evaluated, and it can be concluded that the gas detection capability is strongly influenced by distance and room environment. For an open kitchen with a threshold of 400 ppm, the sensor successfully detects gas leaks at distances up to 10 cm. However, it fails to detect at distances greater than 11 cm. Whereas for a closed kitchen with a threshold of 1500 ppm, the sensor showed better performance, successfully detecting gas leaks at distances up to 15 cm but failing at distances greater than 16 cm. The results demonstrated the system's success in detecting gas leaks, classifying fires, and facilitating emergency communication.

Corresponding Author:

Dhimaz Purnama Adjhi,
Department of Computer Engineering,
Universitas Pendidikan Indonesia,
Jl. Dr. Setiabudhi No. 229, Isola, Kec. Sukasari, Kota Bandung.
Email: dhimaz@upi.edu

1. INTRODUCTION

In the context of a modern world characterized by increasingly more digital connections, technological advancements have brought major implications to various sectors, including the industry [1]. Safety is a top priority in any industrial environment [15]. One aspect that requires special attention is safety in industrial kitchen environments, especially in food cooking processes that require close monitoring of fire risks [14]. Industrial kitchens are the center of vital activities in mass producing food, but they are vulnerable to the risk of fire due to gas leaks such as L.P.G., which is a crucial aspect [7].

In an industrial kitchen, LPG, which is generally the main source of energy as it is used in the cooking process, poses a significant risk if leaks are not detected early [8]. Industrial kitchens are often a vulnerable environment for accidents or fire incidents caused by LPG (Liquified Petroleum Gas) leaks [9]. The hazards posed by LPG leaks are not only health threats to employees but include potential explosions, fire risks that can threaten the safety of workers, property, and the surrounding environment [16]. Therefore, the need for the development of a smart and integrated system to accurately detect leaks and address potential explosion and fire hazards becomes very important in this context.

The purpose of this research is to develop a system capable of efficiently and responsively detecting LPG leaks in an industrial kitchen environment with Internet of Things (IoT) technology. This system aims to detect leaks and classify fires appropriately through the integration of Artificial Intelligence (AI). Integration with the social media chatbot platform is also designed to provide an effective and scalable solution for monitoring, detecting, and responding to emergencies in industrial kitchen environments [2]. The solution proposed in this research is based on the integration of IoT technology and Artificial Intelligence.

Using devices such as ESP32 and MQ-2 sensors for these technologies enables accurate monitoring of gas leaks, as well as the ability to classify fires with high responsiveness using OpenCV on the ESP32-CAM. The system also utilizes PWM action control and automation to effectively adjust the speed of the exhaust fan according to the level of leakage detected. When a gas leak is detected, the exhaust fan will run at maximum speed (PWM 255) to increase the flow and discharge of gas levels in the kitchen, thereby increasing the level of safety as well as the effectiveness of electrical resources. In addition, the integration of social media chatbots is an important part of this solution. With this chatbot, users can effectively monitor video streaming of the kitchen LPG situation, control the action of the exhaust fan, and later receive immediate notifications in emergency situations such as gas leaks or fires. The authors then implemented FreeRTOS into all system processes for the purpose of improving the system's processing efficiency and overall logic.

This solution brings innovation in addressing industrial kitchen safety. The combination of IoT and AI technology enables more responsive detection of gas leaks and fires, increasing effectiveness in managing emergencies. The integration of social media chatbots extends the reach of users in controlling and monitoring the kitchen situation directly with immediate notifications in emergency situations. The implementation of FreeRTOS will also improve system processing efficiency and logic in system reliability. With this solution, this research proposes a smart integrated solution based on IoT and AI to improve safety in industrial kitchens. Early detection of LPG leaks, rapid response to fires, and direct control and monitoring via social media chatbots open up new avenues in managing accident risks. The integration of these advanced technologies provides a solid foundation for a responsive safety monitoring system, minimizing potential fire hazards due to LPG leaks. It is hoped that this contribution will be an important step in creating a safer and more secure industrial kitchen environment.

2. METHODS

2.1 Research Implementation Stages

The research was carried out based on a series of steps that had been planned previously. The flow of the research stages is illustrated through a flowchart that presents the sequence of activities from start to finish. Each step in the flowchart details the processes carried out, including data collection, hardware & software testing, and experiments conducted to test the validity of the system concept built.

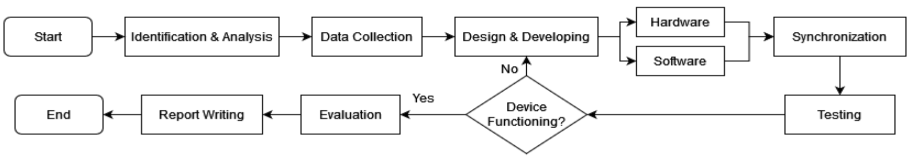


Figure 1. Research Flow Stages

2.2 Literature Review

Based on research conducted by Daruwati et al in 2021, they investigated the LPG leakage threshold using the MQ-2 sensor in two types of kitchen rooms: open and closed [4]. The results of their research show that the threshold for LPG leakage in an open kitchen room is around 600 ppm [12], while in a closed kitchen room, it reaches around 1000 ppm [4]. From this study, it was found that the difference in gas leakage threshold occurred due to factors such as distance, gas dispersion, and sensor sensitivity [4]. This study became the basis of reference in setting gas leakage thresholds for two different types of kitchen rooms. In the current study, the author uses these findings as a guideline to reset the gas leakage threshold on the MQ-2 sensor that will be placed in an open and closed kitchen room. By making a slight adjustment to the resistance of the MQ-2 sensor used and owned by the author, this research shows that the LPG leakage threshold in an open kitchen room is 400 ppm, while in a closed kitchen room, it increases to 1500 ppm.

Based on previous research by Satriyo in 2022, the emphasis on LPG leak detection in the kitchen indicates the importance of using exhaust fans to release gas levels into the air outside the kitchen [12]. In addition, the previous research used flame sensors to detect fires caused by LPG, with monitoring and notification arrangements made through the social media Telegram bot platform (HTTP Protocol) [12]. In the current research adaptation, the approach retains the use of a mini alarm buzzer, exhaust fan, and Telegram bot. However, the author changes the exhaust fan output approach to work on PWM (Pulse Width Modulation) automation and can be controlled via a Telegram bot. That way, the level of safety and effectiveness of electrical resources is expected to increase.

Then, the authors implemented fire detection by utilizing artificial intelligence through OpenCV. The system uses a pre-trained-model approach, which is a model that has been pre-trained on a large and diverse dataset to perform a specific task, in this case, detecting fires. These pretrained models allow the system to recognize fire-related patterns more effectively without having to train the model from scratch, which can take more time and resources [11]. The pretrained-model used in this system is the Cascade fire detection model type in OpenCV. Cascade fire detection is a technique in computer vision that uses a series of trained classifiers to detect objects, in this case fire. This technique works by processing an image through several stages of classifiers, where each stage progressively narrows the possible area containing the object of interest, thereby improving detection accuracy and efficiency [11]. This cascade fire detection model is integrated with the help of ESP32-Cam as input to perform classification on streaming video. The classification process is performed on a cloud server using OpenCV, which enables faster data processing and the ability to handle larger volumes of data. An additional step required in this research is to port forward the local IP of the ESP32-Cam to a local server to enable public streaming that can be accessed by Telegram bots, as well as facilitate the OpenCV classification process on the cloud server [3].

Based on previous research conducted by Arm et al in 2022, the study focused on measuring the performance of FreeRTOS on a multi-core ESP32 [10]. The results showed that using Semaphore-type FreeRTOS on ESP32 provides good efficiency and responsiveness [10]. In the context of the research being conducted, the author refers to these findings to implement FreeRTOS in the Internet of Things and Artificial Intelligence-based fire detection and classification systems to be built. FreeRTOS on ESP32-Cam Video Streaming aims to increase the responsiveness of streaming after port forwarding, which was previously only able to be accessed by one user to be accessed by ten users at once. That way the system that will be built by the author allows ESP32-Cam to stream for OpenCV Classification and streaming to add the "Streaming" feature to a Telegram Bot. In addition, the implementation of classifying fires in LPG leak detection is expected to increase the efficiency of each task involved. Finally, previous research also inspired the author to add the Asynchronous Await process to Python OpenCV in the process of classifying LPG fires in the kitchen, which is expected to improve the performance and responsiveness of the classification process [5].

2.3 System Implementation Design

System implementation design refers to the comprehensive design of the system to be built. It includes the technical specifications and functionality of each piece of hardware and software used in the system, as shown in Tables 1 and 2.

Table 1. Functionality of Each Hardware

Hardware Name	Usability
Microcontroller ESP32	As the brain of the LPG leak detection, it performs control processing & monitoring on the Telegram bot.
ESP32-Cam OV2640	As the brain for processing streaming video in classification and monitoring
Sensor MQ-2	As a sensor for gas leak input in reading gas ppm levels
Exhaust Fan 12V	As an automation output in removing LPG leakage levels in the kitchen
Mini Alarm Buzzer	As a reminder output around the kitchen in case of LPG leakage
Motor Driver L298N	As a motor driver module that can control the PWM exhaust fan
Breadboard	As a PCB prototype board to connect some components
USB & Jumper Cable	As a power and data transfer between components
Adapter DC 12V	As a power source for the exhaust fan
DC Jack Female	As a connector the 12V adapter for the exhaust fan to the L298N driver
Powerbank 5V	As a power source for the ESP32 and ESP32-Cam
Local Server Ngrok	As a server that allows public access to the local server by forwarding ports, converting the local IP of the ESP32-Cam into a public IP for video streaming.
Cloud Local OpenCV	This is a server placed in the cloud to perform fire classification tasks on LPG in industrial kitchens. If a fire is detected, this server will send an alert and capture an image for the Telegram bot.

Table 2. Functionality of Each Software

Software Name	Usability
Arduino IDE & VSCode	As a C++ & Python Text Editor to design software for embedded systems, supported by libraries such as Universal Telegram Bot and FreeRTOS.
OpenCV	As a library that is useful for performing fire detection classification
Ngrok	As software for port forwarding Local IP to Public IP
Fritzing & Diagram Net	As software in designing Internet of Things systems

 DOI: 10.30998/faktorexacta.v17i3.21920

Then, the block diagram and architecture diagram of the system help in visualizing how the components are interconnected and work together; the process can be explained in Figure 2 and Figure 3.

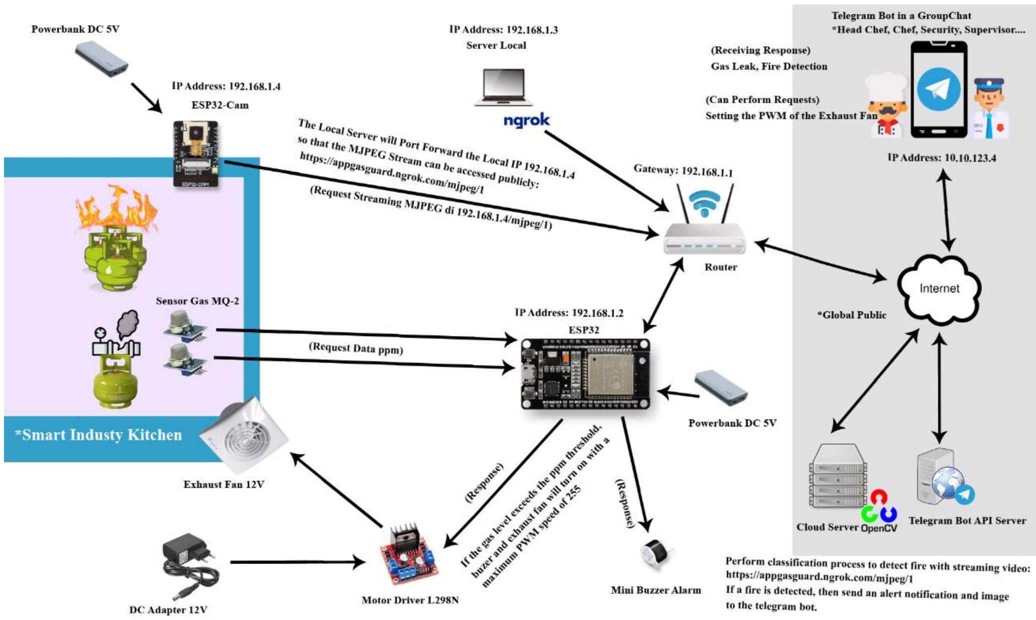


Figure 2. Architecture Diagram of the System

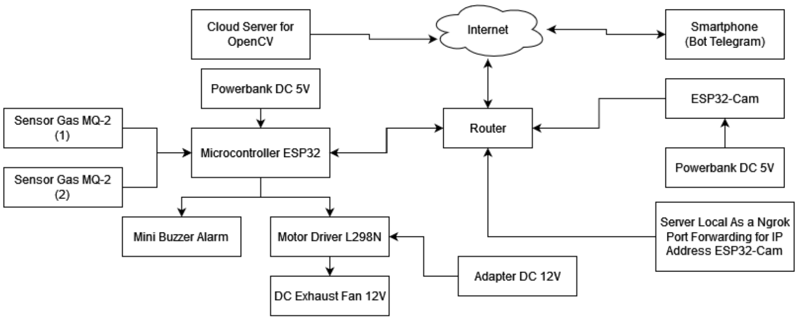


Figure 3. Block Diagram of the System

The system flowchart provides an overview of the system workflow, showing the processes that occur from input to output in the system. The flowchart of the entire system can be seen in Figures 4, 5, 6, and 7.

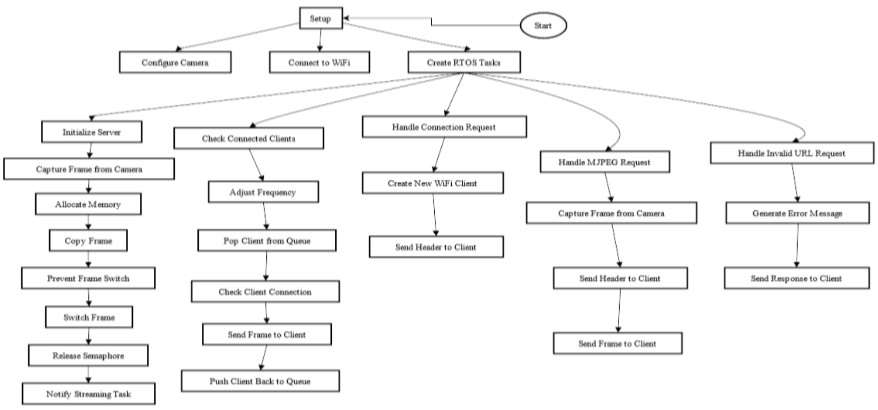


Figure 4. ESP32-Cam System Flowchart for Video Streaming

Figure 4 illustrates the series of processes that occur in the ESP32-Cam system designed to stream video. The process starts with the activation of the ESP32-Cam device, where the camera sensor takes continuous video. The captured video M.J.P.E.G. (Motion JPEG) is then processed and prepared for streaming. Through the transmission process, the streaming video is widely accessible to users connected to the same network as the ESP32-Cam. Once completed, the streaming process is stopped to save device resources.

Figure 5 explains the workflow of the system designed to detect LPG leaks using the MQ-2 sensor on the ESP32. When the sensor detects a leak, the information is sent to the Telegram Bot system to provide notification to the user. The process begins with continuous monitoring by the MQ-2 sensor for gas leaks. If a leak is detected, the ESP32 will trigger the Telegram Bot to send a notification message to a predetermined user. The Exhaust Fan automation will turn on with a PWM speed of 255 (maximum) so that the level of LPG leakage in the surrounding kitchen disappears. The user can later control the Exhaust Fan such as turning it off and on with a PWM speed of 100.

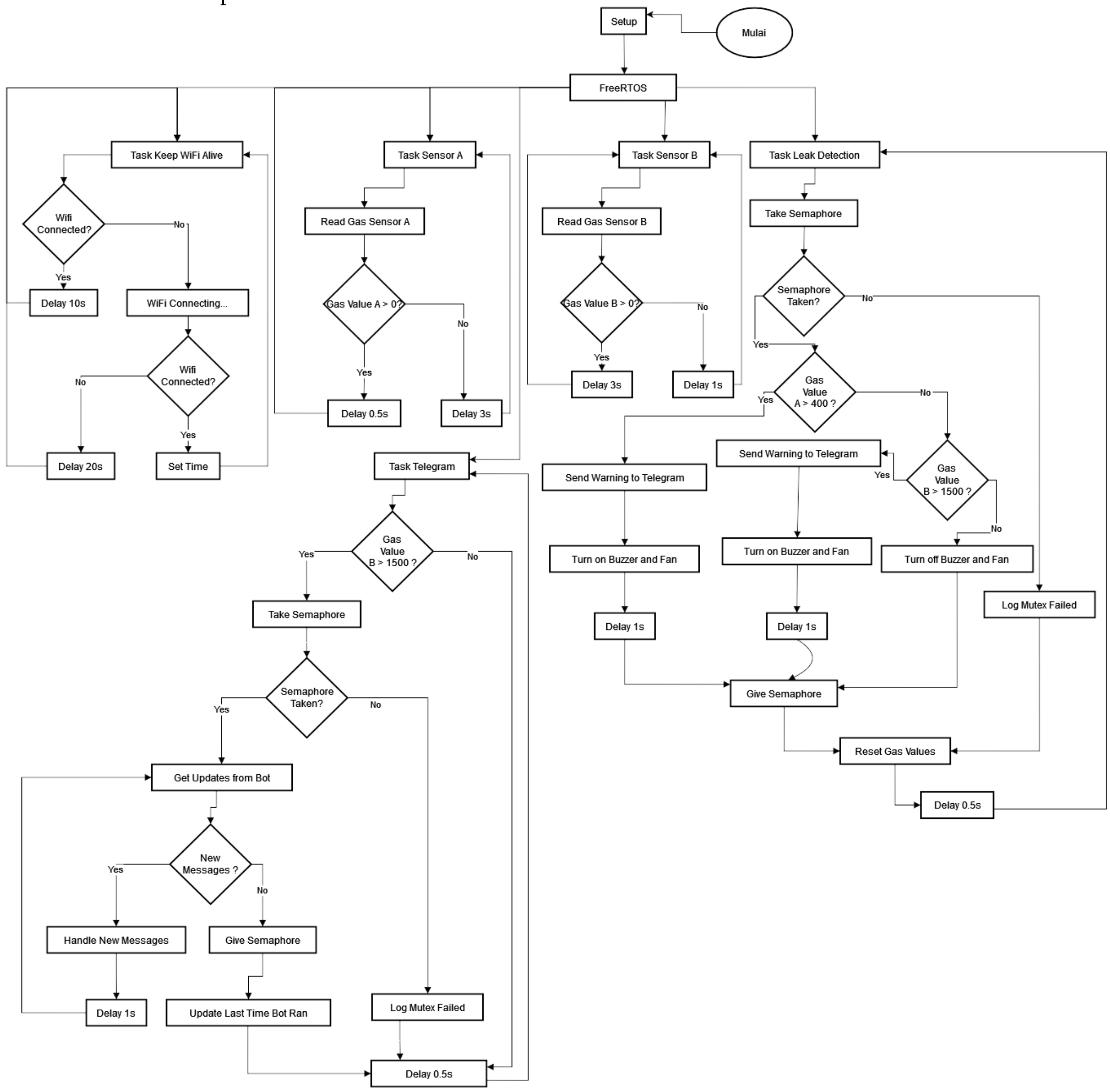


Figure 5. Flowchart of LPG Leakage System and Telegram Bot on ESP32 and Sensor MQ-2

Figure 6 illustrates the flow of the fire detection classification process performed on the cloud server using OpenCV. The initial step is to receive streaming video data from the ESP32-Cam Public IP which has been port forwarding previously. Next, OpenCV will run the classification process using the Pretrained-model method with the cascade fire detection model type to identify fires in the received data. After the classification process has detected a fire, the fire detection results are sent back to the relevant device for further action, such as notification and storing the captured image on server then sending the capture results to the Telegram Bot.

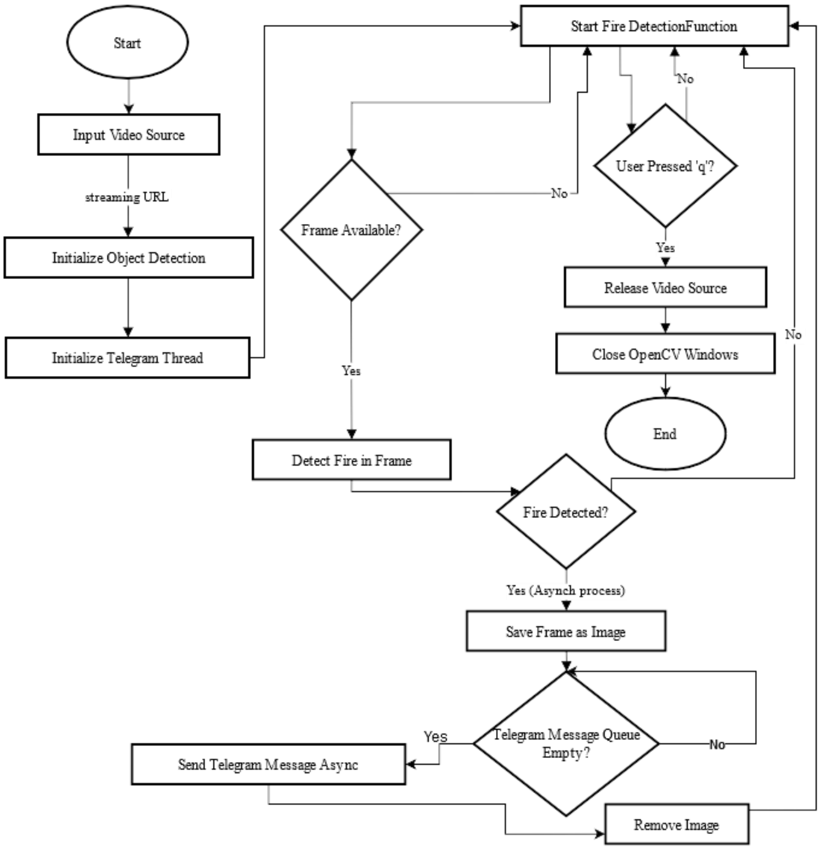


Figure 6. Flowchart for Fire Detection Classification on OpenCV Cloud Server

Figure 7 describes the local IP port forwarding process from the ESP32-Cam device to the local server using the Ngrok service. The initial step of this process is to configure and start the Ngrok service on the local server. After that, the ESP32-Cam device will connect to the Ngrok service through an available internet connection. Ngrok will handle the local IP port forwarding process from the ESP32-Cam to the local server by providing a temporary URL address that can be accessed from the outside internet network. This public URL will be used for video streaming classification on the OpenCV cloud server and monitoring the "streaming" feature on the Telegram bot.

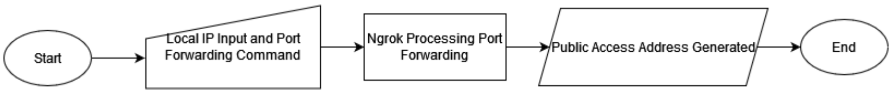


Figure 7. Flowchart for Port Forwarding IP Local ESP32-Cam on Ngrok Local Server

2.4 Hardware and Software Development

Hardware and software development are carried out according to pre-designed specifications. The software repository (Github) that is built contains the source codes used in the development of the entire system, as shown in Figure 8. Then, wiring the hardware components with attention to compatibility and functionality is involved, as shown in Figure 9 [6].

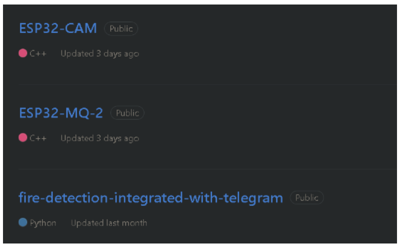


Figure 8. Coding for All System Stored in Github Repository

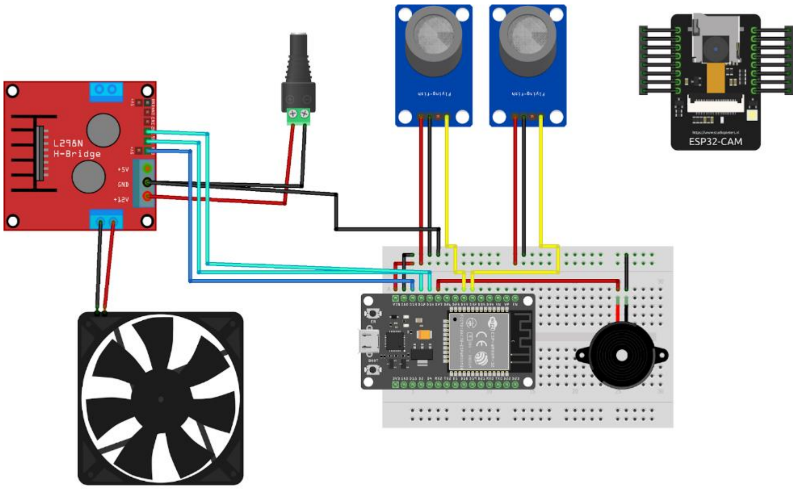


Figure 9. Wiring Components Hardware

3. RESULT AND DISCUSSION

In this Results and Discussion chapter, a comprehensive test of the system features that have been developed using the Black-Box method is conducted. This test aims to comprehensively test the response and performance of the system from the user's perspective without regard to its internal implementation [13]. Figure 10 illustrated the test is conducted by exploring various parameters of the object under test, which includes a variety of situations that may occur in an industrial kitchen environment. This is done to observe the reaction of the system to various conditions that have been previously identified.

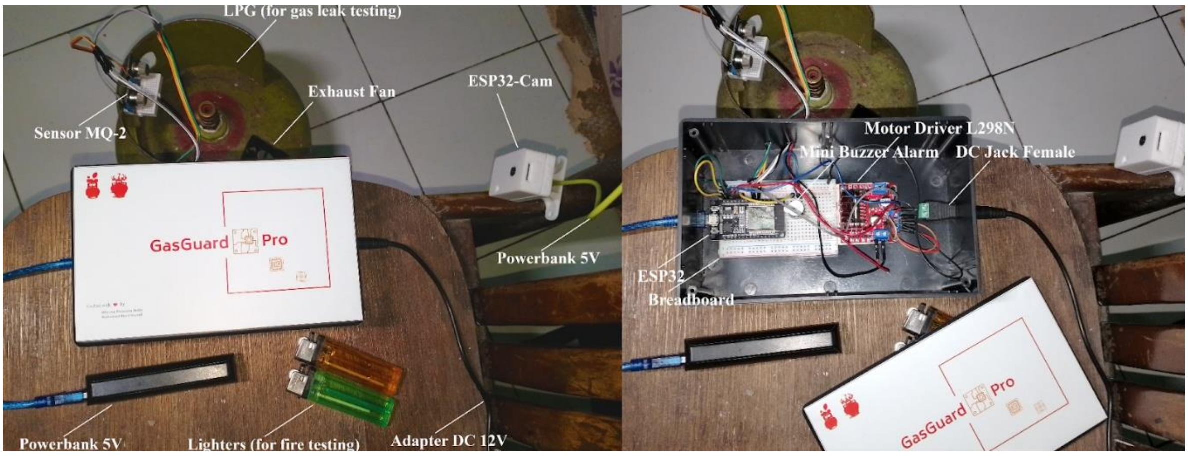


Figure 10. Hardware Implementation Final Results

Each parameter was tested with various scenarios and inputs to see how the system responded to each situation. The results of the tests are systematically recorded in a table that includes the object parameters tested, the system reactions observed, the test results, and documentation that supports the authenticity of the tests. An analysis Table 3, Table 4, and Table 5 of these test results is then conducted to evaluate the performance of the system, correct any deficiencies that may be found, and conclude the overall achievements that have been accomplished by the developed system.

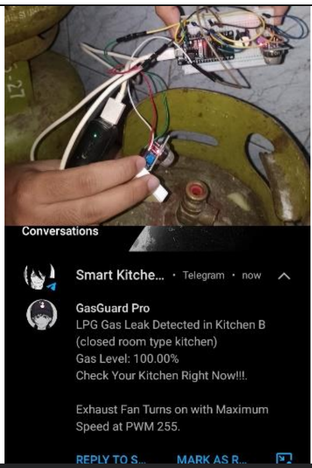
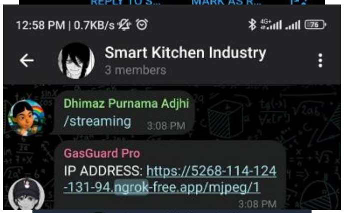
Table 3. Gas Leakage Testing Against Distance

Room Type Object	Distance	Results
Sensor MQ-2 (Open Kitchen), Threshold 400 ppm	< 5 cm	Gas Leak Detected Successfully
Sensor MQ-2 (Open Kitchen), Threshold 400 ppm	6-10 cm	Gas Leak Detected Successfully
Sensor MQ-2 (Open Kitchen), Threshold 400 ppm	11 cm >	Gas Leak Detected Unsuccessfully
Sensor MQ-2 (Closed Kitchen), Threshold 1500 ppm	< 5 cm	Gas Leak Detected Successfully
Sensor MQ-2 (Closed Kitchen), Threshold 1500 ppm	6-10 cm	Gas Leak Detected Successfully
Sensor MQ-2 (Closed Kitchen), Threshold 1500 ppm	11-15 cm	Gas Leak Detected Successfully

 DOI: 10.30998/faktorexacta.v17i3.21920

Sensor MQ-2 (Closed Kitchen), Threshold 1500 ppm	16 cm >	Gas Leak Detected Unsuccessfully

Table 4. Whole Feature Testing Using the Black-Box Method

Objects Tested	System Reaction	Results	Documentation
Detecting LPG Leaks	When an LPG leak is detected and exceeds the ppm threshold, the system reacts by sending a notification alert to Telegram Bot. Then, the exhaust fan automatically turns on with a maximum PWM speed of 255, and the mini buzzer alarm turns on.	Successfully	
Monitoring the Situation of LPG in the Kitchen	When the user commands "/streaming", the Telegram Bot system will send a link in the form of the IP Address of the Public ESP32-Cam that has been done Port Forwarding to be directed to the streaming website.	Successfully	
OpenCV ESP32-Cam Classification of Fire Detection of LPG Flames	When a fire appears on the LPG, the system classifies it as fire detection, captures the situation, and sends an alert to the Telegram Bot.	Successfully	
Store the captured image if a fire is detected on the Cloud Server	If the OpenCV classification detects a fire, then capture the ESP32-Cam image to send to the Telegram Bot	Successfully	
Request Control to Manually Enable and Disable the Exhaust Fan on Telegram Bot	When the user sends the command "turnon_exhaust_fan_pwm100", the system will react to turn on the exhaust fan with a PWM speed of 100. And if the user sends the command "turnoff_exhaust_fan," then the system will respond to disable the exhaust fan	Successfully	

Port Forwarding ESP-32 Local IP to Public IP	On the Ngrok Local Server, the system will successfully perform port forwarding so that the streaming video is public and can be viewed by streaming users and processed by the OpenCV Cloud Server.	Successfully	

Table 5. Testing Data Communication (HTTP Protocol) Against Delay

Data Delivery Object	Delay	Results
Sending Gas Leak Alert Notifications on Telegram Bots	1s	Successfully
Automation of Exhaust Fan when there is Gas Leakage	1s	Successfully
Request Control Exhaust Fan pada Bot Telegram	1s	Successfully
Streaming and Monitoring LPG conditions around the Kitchen	2s	Successfully
OpenCV Classification Process on ESP32-Cam	4s	Successfully

For classification on the OpenCV Cloud Server using a trained model, Cascade refers to a pre-prepared or pre-trained model to accomplish a task relevant to its specifications during training. In this case, the model has been explicitly pre-trained for fire recognition [11]. Testing of data communication through HTTP Protocol has been carried out with a focus on assessing the level of delay in the communication process. The primary purpose of this test is to evaluate the performance of the system in transferring data via HTTP protocol and check how fast or slow the system responds to data requests. Various scenarios have been tested to ensure the system can handle various loads and network conditions that may occur. Figure 11 shows the results of delay testing on data communication using HTTP Protocol, which can be an essential part of evaluating overall system performance in managing and transferring data.

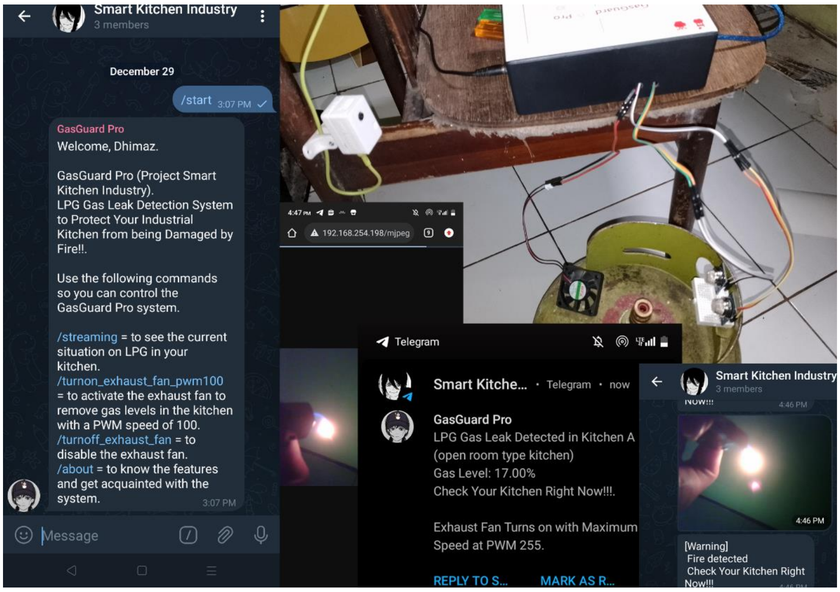


Figure 11. Final Result Telegram Bot as Monitoring Notification Request and Response

4. CONCLUSION

This research successfully developed an LPG leak detection and fire classification system using IoT and AI technologies, which can improve safety in industrial kitchens. Implementing these technologies enables early detection and response to gas leaks, which is the main objective of this research. The developed system shows that the AI model can detect fire objects to prevent fires, and integration with Telegram Bot allows monitoring and response in the form of alerts and the action of exhaust fans that will run. The black-box testing results show that the system able function properly as expected, but also improve efficiency in managing emergencies. The performance evaluation concluded that distance and room environment affect the gas detection capability. In an open kitchen, the threshold value is 400 ppm; for a closed kitchen with a threshold of 1500 ppm, the sensor performs better, successfully detecting gas leaks at a distance of up to 15 cm, but failing at a distance of more than 16 cm.

The application of freeRTOS in this system also contributes to processing efficiency and system stability, which are essential aspects of industrial safety systems. The impacts of this research include reducing the risk of accidents due to gas leakage, increased awareness and preparedness in dealing with emergencies, and potential operational cost savings by reducing the risk of property damage and operational disruption. The system can be widely adopted in various industrial kitchens, ultimately improving overall safety standards. However, further research is needed to test this system on a broader scale and to develop additional features that can enhance the functionality and scalability of the system. As such, this research provides a foundation for further development in IoT-based industrial safety and artificial intelligence.

REFERENCES

[1] A. Hermawanto, A. Ariesani, dan M. Anggraini, "Globalisasi, Revolusi Digital dan Lokalitas: Dinamika Internasional dan Domestik di Era Borderless World," Undergraduate Thesis, 2020.

[2] A. R. Yuniarti, M. Munawir, W. Suteddy, R. Muhammad, dan M. I. Ardimansyah, "Pelatihan Pembuatan Media Pembelajaran Online Interaktif berbasis Chatbot untuk Guru SMA/SMK di Kota Bandung," Jurnal PengaMAS, vol. 5, no. 2, pp. 107-119, 2022.

[3] A. Shukla dan R. Diwan, "IoT Based Load Automation with Remote Access Surveillance using ESP 32 Cam and ESP 8266 module," Annals of the Romanian Society for Cell Biology, pp. 6904-6914, 2021.

[4] A. Smith, B. Johnson, dan C. Lee, "MQ-2 Gas Sensor using Microcontroller Arduino Uno for LPG Leakage with Short Message Service as a Media Information," Journal of Sensor Applications, vol. 10, no. 3, pp. 123-130, 2023.

[5] C. Hattingh, Using Asyncio in Python: Understanding Python's Asynchronous Programming Features, Sebastopol, CA, USA: O'Reilly Media, Inc., 2020.

[6] Components101, "MQ2 Gas Sensor Pinout, Features, Equivalents & Datasheet," Internet, 4 Jan. 2018. [Online]. Available: https://components101.com/sensors/mq2-gas-sensor [Accessed: Dec. 30, 2023].

[7] F. Amir, N. Novianda, dan R. Maulana, "Sistem Pendeteksi Kebocoran Liquefied Petroleum Gas Menggunakan Metode Fuzzy Logic Mamdani Berbasis Internet Of Things," Jurnal Teknologi, vol. 12, no. 2, pp. 151-158, 2020.

[8] H. Husny, F. Kurniawan, dan L. Lasmadi, "Pengembangan Sistem Pemantau Kebocoran Gas Elpiji dan Peringatan Dini Bahaya Kebakaran Berbasis Internet of Things," Aviation Electronics, Information Technology, Telecommunications, Electricals, Controls, vol. 4, no. 1, pp. 61-74, 2022.

[9] I. M. Mara, I. G. B. Susana, I. B. Alit, I. G. A. K. Chatur Adhi W.A, dan M. Wirawan, "Penyuluhan Pencegahan Bahaya Kebakaran Penggunaan Kompor Gas LPG Rumah Tangga," Jurnal Karya Pengabdian, vol. 5, no. 1, pp. 9-15, 2023.

[10] J. Arm, O. Baštán, O. Mihálik, dan Z. Bradáč, "Measuring the Performance of FreeRTOS on ESP32 Multi-Core," IFAC-PapersOnLine, vol. 55, no. 4, pp. 292-297, 2022.

[11] K. M. Rahman, "Fire Detection With Python | Computer Vision," Towards Data Science, Aug 27, 2023. [Online]. Available: https://towardsdatascience.com/fire-detection-with-python-computer-vision [Accessed: Jul. 31, 2024].

[12] M. I. Satriyo, "Rancang Bangun Peringatan Dini Terhadap Kebocoran Gas LPG dan Kebakaran Berbasis Internet of Things," Undergraduate Thesis, Universitas Dinamika, 2022.

[13] M. T. Dashti dan D. Basin, "A Theory of Black-Box Tests," arXiv preprint arXiv:2006.10387, 2020.

[14] R. Suciningsih, "Pengaruh Penggunaan Media Film Pendek Terhadap Pengetahuan dan Praktik Mitigasi Bencana Kebakaran pada Karyawan Industri Katering X di Sleman," Undergraduate Thesis, Poltekkes Kemenkes Yogyakarta, 2022.

[15] S. Darmayani, A. Sa'diyah, S. Supiati, et al., "Kesehatan Keselamatan Kerja (K3)," Publisher Widina Bhakti Persada Bandung, Bandung, 2023.

[16] S. Suflani dan P. Harsono, "Identifikasi Potensi dan Manajemen Pencegahan Bencana Industri di Kota Cilegon Provinsi Banten," Jurnal Administrasi Publik, vol. 9, no. 2, pp. 121-243, 2018.