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Research Article

Internet of Things (IoT) Based Real-Time Kitchen Monitoring System

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The emergence of Internet of Things (IoT) has undoubtedly transformed safety, automation, and monitoring systems across various sectors, particularly in smart home environments. This study presents the design and implementation of an Internet of Things (IoT)-based real-time kitchen monitoring and automation system aimed at enhancing safety, efficiency, and intelligent control within kitchen environments. The system was developed to address the limitations of manual monitoring processes, which are often labor-intensive, error-prone, and unreliable in emergency situations. The system integrates multiple sensors to enable real-time alerts and automated responses. Wireless communication is achieved through a Wi-Fi network connected to the Blynk IoT platform, allowing remote monitoring via smartphones and laptops. Upon detection of hazardous conditions such as gas leakage, fire outbreak, abnormal temperature levels, motion intrusion, or low water levels, the system triggers local alarms and transmits notifications to users through the IoT dashboard. Sensor fusion techniques were applied to enhance data accuracy and reduce false alarms. Experimental evaluation was conducted under simulated real-world kitchen scenarios to assess responsiveness, accuracy, and reliability. The results demonstrated an overall system accuracy of 91.8%, with high detection reliability across all integrated sensors and minimal false positives.

Keywords: *Internet of Things (IoT), Real-Time Monitoring, Kitchen Automation, Smart Kitchen*

Introduction

The use of information and communication technologies has had a significant influence on human life. The digital world today is becoming easier and easier to access. These days, social media and the internet are indispensable to everyone. Various internet connection types have enabled people to access the internet more quickly and with greater quality. An extension of this technology is the "Internet of Things," which enables intelligence and connectivity. Smartphone communication, wireless sensor networks, and internet-connected devices work together to achieve this. These system components help deliver the product according to its plan. The Internet of Things helps process automation in the electronics industry and improves current safety regulations (Thompson, 2024). In a while, the traditional kitchen has transformed, and now it is poised for yet another dramatic shift. We are living in a time where our kitchens are getting smarter, more automated, and more efficient thanks to the Internet of Things (IoT). IoT-based kitchen monitoring systems, with an emphasis on appliance automation, are at the vanguard of this revolution. Imagine a kitchen where your phone can monitor the amount of humidity, receive updates when there is a flame in the kitchen, detect when someone enters the kitchen, and receive notifications when there is a gas leak from the burner, hose pipe, or gas cylinder. This is a real-life scenario that is quickly materializing in homes all across the world, not a scene from a futuristic film. The way we use our kitchens is changing as a result of the Internet of Things (IoT) being incorporated into equipment and systems. This indicates that cooking will become more accurate, energy use will be more economical, and we will enjoy our time in the kitchen more. One cannot stress the significance of this technical revolution. The demand for effective and clever kitchen solutions rises as urbanization and smaller living areas both rise. Moreover, IoT-based kitchen systems provide a route to more ecologically friendly household management in light of the growing global movement towards sustainability and the growing awareness of energy saving.

Automation technology is advancing to make human life easier, more comfortable, and less demanding across the board. With a real-time kitchen monitoring system, you can watch and operate your home's kitchen equipment from anywhere in the world using a laptop or smart mobile device. These days, automated systems are favored over manual ones (Gayaki et al., 2023). The Internet of Things, or IoT, is a promising technology that allows you to connect, control, and monitor your kitchen equipment remotely. Real-time kitchen monitoring systems have gained a lot of attention due to the advancements in communications technology. A real-time kitchen monitoring system, or Internet of Things (IoT), connects, monitors, and controls kitchen appliances and behavior (condition) through the use of Internet technology (Bharti et al., 2023). With little to no human contact, a system made of Internet of Things technology (IoT) connected sensors and kitchen appliances may be monitored and communicated on their own. With a real-time kitchen monitoring system, we may simplify activities in and around our living units, such as gas leak detection, flame detection, motion detection, humidity detection, fan control, and so on. A list of ideal conditions is also added, including comfort, convenience, economy, safety, security, and dependability. The Internet of Things is a concept where lots of things can talk to each other. These things include things we wear like watches and cars and machines that make things. There are also lots of sensors that can feel and see things. The Internet of Things is, about all these things being connected and sharing information with each other. The Internet of Things is an idea that can make our lives easier and more fun. These gadgets can be configured to carry out duties and respond either automatically or in response to user input to the demands of the inhabitants (Hassan et al., 2022). The Internet of Things a system that connects objects and the sensors attached to them to the worldwide computer and other networks is the base, for real-time kitchen monitoring and automation technologies. Irrespective of the mode of communication, the objects may comprise non-electronic things such as food and clothes and have the ability to interact, read, recognize, locate, and/or control themselves over the Internet. A real-time kitchen monitoring and automation system is a network of interconnected appliances and equipment in a house that can be controlled remotely and interact with one another (Singh et al., 2023). Because of its improved convenience, energy efficiency, and security, this technology has had a significant impact on how people interact with their homes.

Automation of various functions such as entertainment, HVAC (heating, ventilation, and air conditioning), lighting, and security may be achieved through the integration of various IoT (Internet of Things) devices, sensors, and actuators in real-time kitchen monitoring systems (Sodiq & Mohammad, 2022). Homeowners may remotely monitor and change the settings of these systems from anywhere in the house using tablets and smartphones. Modern technology has been incorporated into real-time kitchen monitoring systems, which improve convenience, effectiveness, and security in houses, revolutionizing residential life in recent years. These systems build a network where different appliances and systems may interact, coordinate tasks, and be managed remotely using Internet of Things (IoT) devices, sensors, and communication protocols.

Problem Statement

The manual procedures frequently used in kitchen monitoring systems today can be labor-intensive, time-consuming, and error-prone. Employees in many kitchens monitor inventory, check temperatures, and ensure compliance with safety regulations during tasks that require regular attention to detail for long stretches of their shifts. Sadly, errors can occur from simple negligence or inaccurate documentation when human oversight is relied upon. The smart kitchen monitoring system gives users basic real-time monitoring and control through an Android app, giving them the ability to track the intended parameters like light levels, temperature, humidity, fan operation, ovens, and possible gas leaks. However, the system has some limitations, which include relying on a small number of sensors, which limits its ability to collect a variety of environmental data, thereby reducing the strength of the monitoring, and having limited automation features that give users limited control over automated responses based on collected data (Kimutai et al., 2022). These limitations make it difficult for the system to ensure a fully automated and intelligent kitchen environment.

Aims and Objectives

The goal of an IoT-based real-time kitchen monitoring system is to improve kitchen efficiency and safety by continuously monitoring sensitive parameters like temperature, gas leaks, appliance status, and other environmental factors, allowing for real-time alerts and automated responses to potential hazards while also providing suitable control of gadgets through a connected device.

Related Work

A proposed Bluetooth-based home automation system (Ann & Lee 2024). An ATmega328P-based Arduino Uno microcontroller board (8-bit RISC architecture). It features six analog inputs, fourteen digital input/output pins (six of which can be used as PWM outputs), and a 16 MHz quartz crystal that is linked to a Bluetooth module (HC-05) that uses a Solid State Relay (SSR) to communicate with two-way electrical appliances. To operate the appliances, a Bluetooth-capable smartphone connects wirelessly to the Arduino Bluetooth board. The system's operation was evaluated to cover a maximum range of 100 meters in an open area and less than 50 meters in a concrete building. A sensor fusion methodology that combines data from multiple sensors to improve object detection and distance estimation (Favelli et al., 2024). The approach aims to enhance reliability and accuracy in various applications, including robotics and automation. The study discusses the integration of different sensor types and the algorithms used for data fusion, highlighting the challenges and potential solutions in the field of sensor technology. This work contributes to the ongoing development of intelligent systems that require robust and precise environmental interaction. Sari & Enriko (2023) designed and developed a gas detection and alerting system aimed at addressing gas leak emergencies. The system focuses on detecting liquefied petroleum gas (LPG) and butane gas, utilizing MQ-5 and MQ-6 gas sensors connected to a microcontroller. Upon detecting a medium gas concentration, the system triggers a high-frequency audible alert via a buzzer. At higher concentrations, the system automatically calls a registered phone number. Real-time monitoring is provided through ThingSpeak, which receives data from the microcontroller every 15 seconds. The authors position their work within the context of increasing dangers associated with gases in flammable or toxic conditions. A comprehensive exploration of advancements in kitchen automation through the development of a highly intelligent culinary robot. This robot is designed to enhance user experience by automating various cooking tasks, thereby addressing the limitations of existing kitchen technologies. The authors highlight the increasing demand for automation in the food industry, driven by the need for efficiency and convenience in cooking processes (Livinsa et al., 2021).

An IoT-based system is designed to detect LPG gas leaks in homes, businesses, and educational institutions (Sodiq, 2024). The authors propose a system utilizing a NodeMCU microcontroller, an MQ-5 gas sensor, and a buzzer to provide local alerts, with the aim of continuous monitoring and remote notifications via a smartphone. The potential integration of an automatic gas valve shut-off system is also explored. Gas leakage detection and alarm system using an Arduino microcontroller, a GPS module, and an exhaust fan (Zabi, 2023). The proposed system uses an Arduino microcontroller system to sense the gas leak with the help of the sensor and GPS module to provide the location for the gas leak where the MQ6 sensor is used in this system interfacing with Arduino and the signal from the sensor is sent to the microcontroller which is connected to communicate with the liquid crystal display and send a signal to the buzzer to sound the alarm when there is leakage and automatically turn on the exhaust fan so that it will suck away the gas from the surrounding premises then also send a message through a GSM module to the occupant of the building. IoT-based kitchen monitoring and control system is used to monitor all kitchen appliances and the working conditions if it is safe for use by the user using a mobile phone or a PC (Letty et al., 2023). These are all integrated through an IoT platform. The appliances are all monitored continuously, and the statuses are noted down and displayed on the ESP-Dash dashboard using pc or a notification pops up on a smartphone. The system detects gas leakage, motion detection and also detects the temperature level in the kitchen if it is high or low. As soon as the device detects or senses any action using the sensors, the data captured by the sensors will be sent as raw data to the microcontroller; the controller processes the data received from the sensors to detect the next line of action. The microcontroller decides when it is required to send a notification and also automatically turns on the buzzer to beep or make a sound for fast notification. The temperature detection system combats the spread of infectious diseases, particularly emphasizing the need for rapid screening in public health contexts (Baballe & Bello, 2022). This system utilizes an infrared sensor that detects by measuring the radiation that these objects give off. This is basically the radiation that the objects emit. This non-contact method is vital for safety and hygiene, especially during health crises like the COVID-19 pandemic. The design includes two LEDs: one indicates that the sensor is actively scanning, while the other changes color based on the temperature detected, green for normal and red for elevated temperatures. The system is not just useful for medical settings but can be implemented in schools, offices, and public spaces to ensure safety. The LED display provides immediate feedback, which is crucial in environments where quick decision-making is needed. This work underscores the role of technology in public health monitoring and management. An advanced security system that uses motion detection to enhance indoor geolocation monitoring (Karaya 2023). Central to this system is the use of microcontrollers, specifically the Raspberry Pi, which acts as the heart of the setup, processing and coordinating the various components. One of the system's primary characteristics is its capacity to integrate video cameras for surveillance purposes, which not only allow for live monitoring but also enable recording that can be accessed at any time. The paper stresses the critical role of connecting video cameras with motion detectors to strengthen the overall security architecture, ensuring that every detected movement triggers an appropriate response. A core component of the system is the use of Passive Infrared (PIR) sensors, which are designed to detect infrared radiation emitted by living organisms. These sensors work by sensing changes in temperature caused by human movement, making them especially effective for detecting intrusions or any unauthorized presence in the monitored area. When a PIR sensor detects such movement, it triggers the system to activate various responses, such as alerting the user.

Methodology

The process of putting together information from sensors to create a better, more reliable, and more complete view of the system or the environment that is being watched is called sensor fusion. Sensor fusion is really important for embedded systems to get information. Embedded systems need to be very accurate, especially when they are used to monitor what is happening around us and make decisions. As embedded systems get better and more reliable, they use sensors to collect and improve the information that sensor fusion provides. This is because sensor fusion helps embedded systems get possible information from multiple sensors.

Components used are

a. **Sensors (Inputs):**

   i. DHT11 sensor (temperature & humidity)
   ii. MQ-2 gas sensor
   iii. PIR sensor (motion detection)
   iv. Flame sensor
   v. Ultrasonic sensor

b. **Controller & Communication:**

   i. NodeMCU (ESP8266)
   ii. Mobile hotspot / Router (Wi-Fi)
   iii. IoT server (Blynk server)

c. **Display & User Interfaces:**

   i. I2C module
   ii. LCD display
   iii. User smartphone
   iv. User laptop device

d. **Actuators & Outputs:**

   i. Buzzer
   ii. DC motor fan (exhaust fan)
   iii. 4-channel relay module

e. **Controlled Loads:**

   i. Socket outlet
   ii. 5V bulb
   iii. DC water pump
   iv. Fan

f. **Power Supply:**

   i. 9V DC supply

Block Diagram and Materials

Fig 1 displays the system's block diagram, which combines several components for intelligent control and monitoring. It uses a NodeMCU microcontroller to collect data from several sensors, including motion, temperature, gas, flame, and ultrasonic sensors.

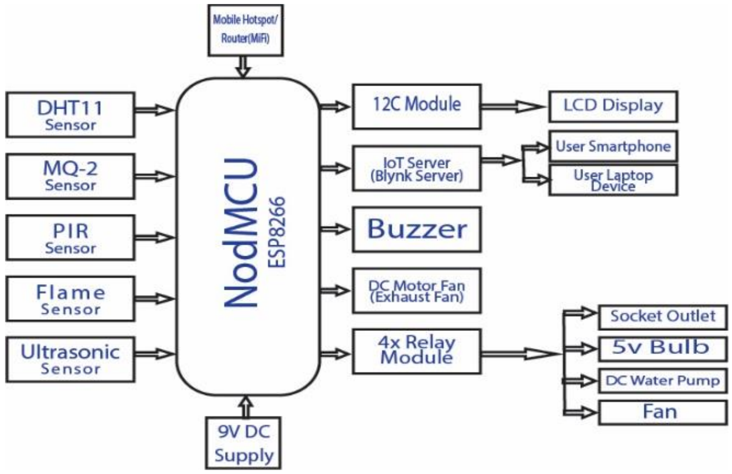

Figure 1. Block diagram of IOT-Based Kitchen Monitoring System

Block Diagram and Materials

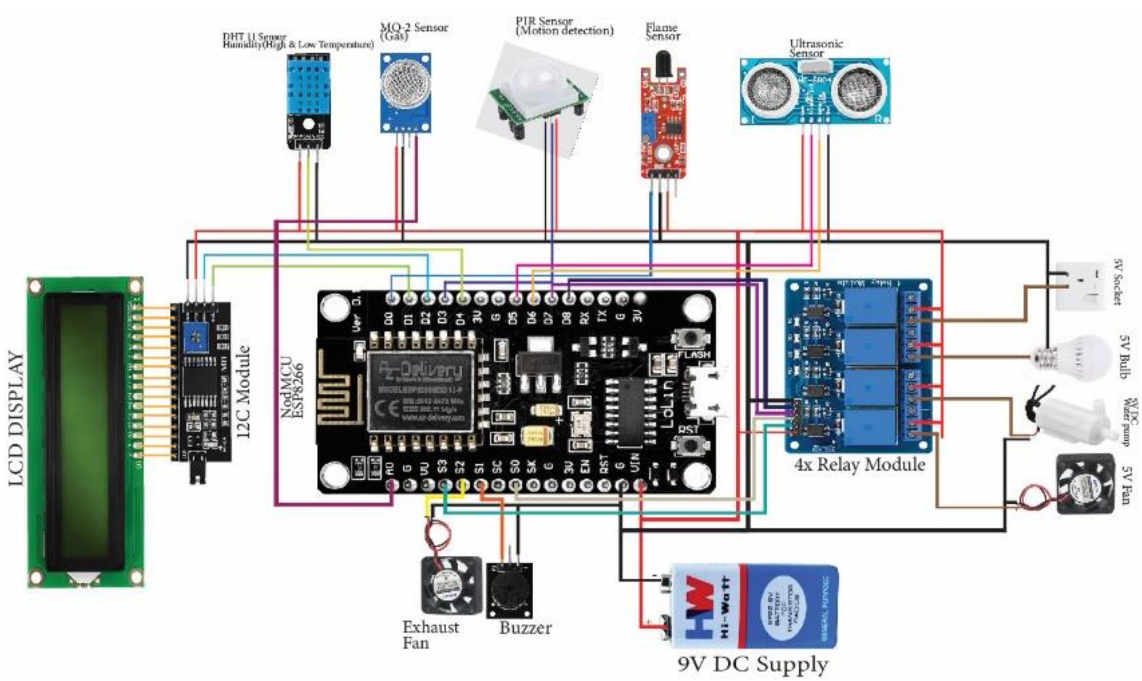

Figure 2. Hardware component connection

The hardware connection shown in Figure 2 depicts the architectural design of the block diagram in Figigure 1.

Results and Discussion

Table 1. Shows the confusion matrix results of the test conducted on the system

Sensor/Test case	True Positive	True Negative	False Positive	False Negative
MQ-2 (Gas Detection)	12	1	0	1
PIR (Motion Detection	9	0	0	1
DHT11 (Temp/Humidity)	10	1	0	1
Flame Sensor (Fire Outbreak)	12	0	0	1
Ultrasonic Sensor (Water Level Test)	10	1	0	1

The results from the various sensor tests were analyzed to assess the system's overall performance and reliability. Each sensor's output was compared with expected values or reference measurements, and the accuracy was calculated to evaluate whether the system met the required operational standards. The sensor testing phase was a crucial step in authenticating the system's capability for real-time monitoring. Each sensor was examined under various conditions to simulate the types of circumstances or scenarios it might encounter in an operational kitchen environment. The aim was not just to see whether the sensors could "work," but to determine whether they could work continuously, quickly, and precisely when an emergency needed attention. The MQ-2 gas sensor demonstrated high sensitivity, accurately detecting hazardous gas levels and triggering alarms, notifications, and automated exhaust fan responses, with an overall accuracy of 92.9% despite a single false negative attributed to environmental or network factors. This test, as shown in the above table, out of 13 trials that were carried out, there were 10 True Positives, 1 True Negative, 0 False Positive, and 1 False Negative. This shows that the system detected 10 trials correctly, while in another case it detected but didn't raise an alarm because it detected a gas but not combustible gas; in the last case, there was a leakage it didn't detect because of network failure. This is in accordance with Alshammari and Chughtai (2020), who observed that the MQ-2 sensor produces a HIGH output when LPG gas is present within the desired parameter, and also noted that the microcontroller triggers an alarm in response to the desired threshold value of detection. The PIR motion sensor performed reliably across short to medium distances, achieving 90% accuracy, though its performance degraded under strong daytime ambient light, causing one false negative at long range. In this phase, out of the 13 trials carried out, 9 were correctly detected, and 1 case wasn't detected because of the interference of high ambient light that interfered with the Infrared Rays. This is in agreement with Amuta *et al.* (2024), verified that PIR sensors detect infrared radiation emission from a moving object, such as people or animals. When an object moves within the sensor's field of view, the sensor detects a change in infrared radiation and triggers an alarm or other response.

The DHT11 temperature and humidity sensor effectively distinguished between safe and unsafe thermal conditions, minimizing false alarms and achieving an accuracy of 91.7%. 12 trials were carried out, 10 (TP) were correct and alarm received while in a 1 (TN) detected but didn't raise an alarm because it sensed that the humidity was high which shows that the heat was artificially introduced since the humidity is still high. This is in accordance with Baballe *et al.* (2022), the DHT11 temperature and humidity sensor detects and can be used for readings and precision in different contexts at the desired threshold value. The flame sensor showed strong fire detection capability, particularly in low-light conditions, with 92.3% accuracy, while occasional daytime false negatives were linked to ambient infrared interference. 13 trails carried out; 12 fire outbreaks were detected, except for 1 that wasn't detected due to high interference of light between the sensor and the fire outbreak. This is in agreement with Teja *et al.* (2022), which states that the flame sensor detects flame at every level within the parameter if there is no bright light across the sensor directly, and when placed in the desired and strategic position for effective detection.

The ultrasonic water level sensor reliably classified low, normal, and full tank conditions, issuing appropriate alerts and achieving 91.7% accuracy. In this phase, 12 trials were carried out; 10 of it where correct. In 1 case, the system detected a low water level and didn't raise an alarm due to low network coverage, and in 1 case didn't detect or send an alarm, which was due to no network coverage. This shows that the water level monitor can't work efficiently without a strong network connection. This is in conformity with Adebola *et al.* (2021), distance measurement of the ultrasonic sensor with respect to the presence of obstacles or obstructions present in the target area is always precise because it continues to check if the obstacle is closer or far away.

Comparative Analysis

Table 2 and Figure 3 demonstrate how reliable and effective Internet of Things technologies are for keeping track of what's happening in a kitchen in time and for automating kitchen tasks. Compare the accuracy of two Internet of Things systems that monitor kitchens in real time. Both studies showed similar and high levels of accuracy (91.8% and 91%). In conformity with Adegoke et al., (2024), Table 2 and Figure 3, shows the comparison result of the current research and the existing knowledge. This shows that the system has been consistent and accurate in all tests, as shown in the above tables. This means that the system is ready and can be accepted in real-world scenarios or use.

Table 2. Comparison results

Title of the research	Accuracy
Internet of Things (IoT) based real-time kitchen monitoring System	Achieved 91.8%
Design and Implementation of Real-Time Kitchen Monitoring and Automation System Based on Internet of Things Hassan et al., (2022)	Achieved 91%

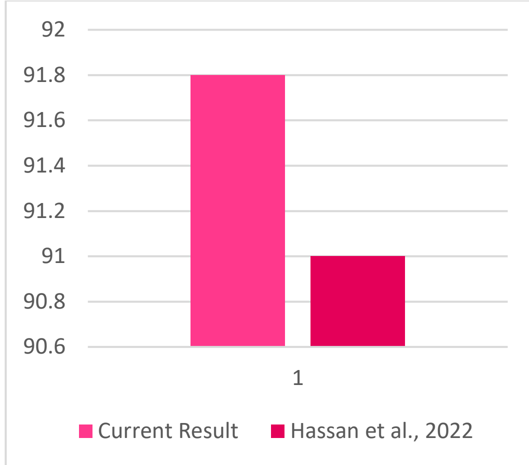

Figure 3. Comparison results

Conclusion

The design, development, and deployment of an Internet of Things-based real-time kitchen monitoring system were the main objectives of this system. A NodeMCU ESP8266 microprocessor controls the system's integration of several sensors, including a MQ-2 gas sensor, a PIR motion sensor, a DHT11 temperature and humidity sensor, a flame sensor, and an ultrasonic sensor for water level measurement. Enhancing kitchen safety, monitoring, and timely alerts to stop mishaps or other system hazards were the goals.

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Author contributions

S. U. Chagwa conceptualized the study, conducted the experiments, collected and analyzed the data, and wrote the original draft of the manuscript.
Prof. P. B. Zirra supervised the research, provide guidance on methodology and interpretation, reviewed and edited the manuscript, and other resources.
All authors have read and approved the final version of the manuscript.

Data Availability

The data used in this study were obtained directly from the sensors of the implemented system. The datasets generated and analyzed during the current study are available with the author upon reasonable request.

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Conflict of interest

The authors declare that there is no conflict of interest, financial or otherwise, related to the publication of this research paper.

Ethics approval

NA

AI tool usage declaration

The authors declare that No AI-assisted tools were used and No AI system was used to generate original scientific claims, data, or research results.

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