Journal of Engineering Science | *Vol. XXIX, no. 3 (2022), pp. 150 - 165*
Fascicle *Food Engineering* *ISSN 2587-3474*
Topic *Food Industry and Management* *eISSN 2587-3482*

https://doi.org/10.52326/jes.utm.2022.29(3).13
UDC 643.3:[004.7:621.391]

RECENT ADVANCES IN SMART KITCHEN AUTOMATION TECHNOLOGIES: PRINCIPLES, APPROACHES, AND CHALLENGES

Buhari U. Umar*, ORCID: 0000-0001-6971-1917,
Olayemi M. Olaniyi, ORCID: 0000-0002-2294-5545,
Idris A. Dauda, ORCID: 0000-0002-2775-6292,
Danlami Maliki, ORCID: 0000-0003-2870-7959,
Cindy P. Okoro, ORCID: 0000-0002-1727-3246

Department of Computer Engineering, Federal University of Technology, Minna, PMB 65, Minna, Niger state Nigeria,
*Corresponding author: Buhari U. Umar, *buhariumar@futminna.edu.ng*

Received: 05. 29. 2022
Accepted: 07. 14. 2022

Abstract. The Internet of Things (IoT) is a growing network of physical devices that are connected to various types of sensors and can share data with the aid of internet connectivity. Safety is an important consideration when designing a house, town, smart kitchen, etc., and it continues to play an important role in today's world. In general, the kitchen is regarded as one of the most crucial tasks in our everyday lives, making it imperative to equip this vital element of human life with smart devices to avoid commonplace incidents such as gas leaks, intense particles in the environment, or fire outbursts. Gas leaks in the kitchen can be dangerous and deadly, resulting in fires if they go unchecked. For smart kitchens, various systems have been built to combat gas leaks and fire outbreaks. However, despite their high precision, these systems each have their own set of flaws that have severely restricted their implementations. The state-of-the-art in gas leakage, fire, and smoke detection in a smart kitchen is discussed in this paper. Different methods of gas leakage and fire detection are also addressed, along with their strengths and weaknesses, as well as products available in the market today.

Keywords: *Internet of things (IoT), smart kitchen, gas leakage, smoke, safety systems.*

Rezumat. Internetul lucrurilor (IoT) este o rețea în creștere de dispozitive fizice care sunt conectate la diferite tipuri de senzori și pot partaja date cu ajutorul conexiunii la internet. Siguranța este un aspect important atunci când proiectați o casă, un oraș, o bucătărie inteligentă etc. și continuă să joace un rol important în lumea de astăzi. În general, bucătăria este considerată una dintre cele mai cruciale sarcini din viața noastră de zi cu zi, ceea ce face imperativ să echipam acest element vital al vieții umane cu dispozitive inteligente pentru a evita incidentele obișnuite, cum ar fi scurgerile de gaz, particulele intense în mediu sau incendiul. izbucniri. Scurgerile de gaz în bucătărie pot fi periculoase și chiar mortale, ducând la incendii dacă nu sunt controlate. Pentru bucătăriile inteligente, au fost construite diverse sisteme pentru combaterea scurgerilor de gaze și a focarelor de incendiu. Cu toate acestea, în ciuda preciziei lor ridicate, aceste sisteme au fiecare propriul set de defecte, care le-au restricționat sever implementările. Echipamente de ultimă generație în detectarea scurgerilor de gaze, a incendiilor și a fumului într-o bucătărie inteligentă sunt discutate în această lucrare. De asemenea, sunt abordate diferite moduri de scurgere de gaze și de detectare a incendiilor, împreună cu punctele forte și punctele slabe ale acestora, precum și produsele disponibile pe piață astăzi.

Cuvinte cheie: *Internetul lucrurilor (IoT), bucătărie inteligentă, scurgeri de gaz, fum, sisteme de siguranță.*

1. Introduction

Cooking is often performed in the kitchen and is considered one of the most important activities in our daily lives and is one of the most important tasks that people do [1]. The use of the gas cylinder, which is popular in most smart kitchens, is rapidly growing, but it is also extremely dangerous because it can trigger fires. This work is motivated by the dangers posed by gas leakage, CO contamination, and fire outbreaks in humans and their resources. Gas leaks in the home are normally caused by equipment that has been improperly installed, operated, or damaged [2]. Gas leakage, lit cigarettes, short circuits, and overheating mobile phones have all been identified as common causes of fire outbreaks at home. While high temperatures in the frying pan, vegetable oil, and old oil in a deep fryer are all common sources of smoke in the kitchen, etc. [3]. Since natural gas is odourless, it cannot be detected by smell alone. As a result, a chemical (Mercaptan) is applied to give it a distinct odour to warn people in the event of a leak [4]. Some people, on the other hand, have a very weak sense of smell, which has contributed to the development of gas detection systems. Fire detection systems are designed to detect fires in their early stages (which includes all types of fires), giving people precious minutes to flee to safety, saving lives, and reducing property damage, as well as taking decisive measures to stop the fire from spreading [5]. Figure 1 shows a typical smart kitchen with smart lights, a smart food heater (microwave), intrusion detectors, a smart electric cooker, a smart kitchen seat, smart cooling appliances, and so on. Smart systems, smart meters, smart appliances, smart power outlets, and sensing devices are installed in the smart kitchen to encourage the development of intelligent solutions for the everyday life of people [6].

Figure 1. A Typical Smart Kitchen [6].

Various studies on gas, smoke, and fire detection have been carried out; however, this paper aims to explore the state-of-the-art achievement in gas leakage, fire, and smoke detection technologies in smart kitchen automation, as well as the research gap and open issues that need to be addressed in the field of smart kitchen automation technologies. The rest of the paper is organized as follows: an overview of gas leakage, fire, and smoke detection system in a smart kitchen is presented and discusses gas leakage and detection system in a smart kitchen. Also, their strength and weakness are discussed. A smoke and smoke detection system in a smart kitchen is presented, and the fire and fire detection system in a smart kitchen is discussed as well. Lastly, related works in gas, fire, and smoke detection systems in a smart kitchen; open issues and challenges in gas leakage, smoke, and fire detection in a smart kitchen; and the conclusion of the research work.

2. Overview of Gas Leakage, Fire, and Smoke Detection Systems in A Smart Kitchen

Protection systems are also referred to as fire, smoke, and gas detection systems. System safety is a branch of systems engineering those aids in the management of program risk. To improve protection, engineers and managers use engineering and management concepts, requirements, and techniques. The goal of a safety system is to improve safety by detecting and removing or managing safety risks by designs and/or procedures that are focused on appropriate system safety priorities [7]. When designing any detection device, there are a variety of existing systems and techniques to consider, some of which are discussed in this paper.

3. Gas Leakage and Detection System in a Smart Kitchen

As poisonous gases and vapours build up to unhealthy levels, or when the air is depleted of oxygen, it can be highly dangerous to people, buildings, and equipment [8]. The safety and health of a family, machinery, and property must be entrusted to perfectly working sensors. This is because human sensory organs are often unable to detect airborne threats, and even when they do, they do so too late.

As a result, hazards must be detected in real-time and consistently, because false alarms trigger production downtime. As a result, the sensor is the most crucial part of a gas detection device.

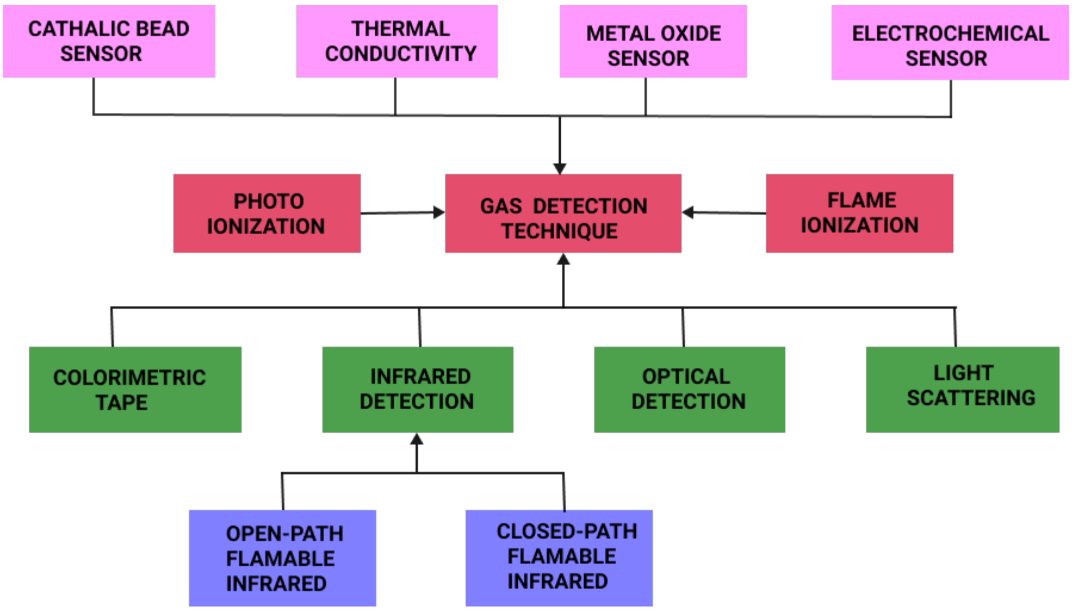

Figure 2. Various Gas Leakage Detection Techniques.

It converts the measured variable into an electrical signal using chemical or physical processes, depending on the type of sensor. The accuracy with which dangerous substances suspended in the air can be detected is largely determined by the sensors used to detect them. As a result, both the gas detector and the sensor must be perfectly balanced [9]. Catalytic Bead Sensor, Thermal Conductivity, Infrared Gas Detection, Electrochemical sensor, Metal oxide sensors, Colorimetric tape, Optical Gas Detection, Open-path Flammable Infrared Gas Detection, Open-path Toxic Infrared Gas Detection, Photo Ionization, Flame Ionization, and light scattering are some of the techniques used to design gas detectors. Figure 2. depicts the most often used techniques for detecting gas leaks.

3.1. Catalytic Bead Sensors

A heated catalytic bead (usually platinum or palladium) burns at a lower temperature than combustible gas concentrations (a concept identical to that of a catalytic converter in a car). The thread in the bead heats up as the gases burn. The resistance of the wire increases as the temperature rises. This temperature rise is compared to a non-catalytic reference bead using a Wheatstone bridge to provide a reading of the fuel gas [10].

3.2. Thermal Conductivity

Heat is transported at various rates by different gases. As a result, in the air, the heated wire can lose heat at a different rate than in gases like helium. This distinction can be used in the development of a gas detector. Since low-level heat loss is difficult to detect accurately, this approach is typically used only when the percentage of gas volume is detected. The detection of the volume percent of combustible gas, helium, and carbon dioxide is one of the most common applications [10].

3.3. Colorimeter Sensors

If any chemicals are exposed to other chemicals during a chemical reaction, they will change color. This idea is used to construct a "spot" that can then be seen or sensed electronically. This approach is used in low-tech detector tubes as well as detection systems developed specifically for the semiconductor gas detection industry (arsine, phosphine, etc.) [10].

3.4. Metal Oxide Sensors

Some metal oxides (such as tin) have semiconducting properties that make them ideal for gas detection. Fuel gases and hydrogen sulfide are popular applications, but the device can also detect a wide range of other chemicals. The electrical resistance of these semiconductors decreases when they are exposed to certain gases. The decrease in gas concentration can then be measured and related. These sensors are often used in hostile environments because they are robust and long-lasting [10].

3.5. Electrochemical Sensors

To oxidize or reduce a chemical, electrochemical sensors use two or more electrodes in an electrolyte. It is possible to make sensors for a variety of gases by changing the electrode materials and electrolytes. For the detection of oxygen and poisonous gases, electrochemical sensors are widely used. They are not usually used for organic compounds [10].

3.6. Infrared Detection

The use of infrared light to detect combustible hydrocarbon gas is known as infrared gas detection. A source of infrared light, an optical filter to select the correct wavelength, and an optical infrared receiver make up the detector. Hydrocarbon molecules in the gas absorb some of the infrared energy as it passes through the vacuum between the source and receiver. As a measure of the amount of hydrocarbon gas present, the receiver detects a decrease in receiving energy. The output signal of an Infrared Gas Detector is also compensated for the effects of temperature, humidity, and the presence of moisture or dirt on the optical filters by using two wavelengths of infrared radiation, one active wavelength for gas absorption and the other as a reference wavelength to compensate the output signal of the Infrared Gas Detection device for the effects of temperature, humidity, and the presence of moisture or dirt on the optical filters. Open-path detection and close-path (point) detection are two classifications of infrared gas detection systems [11]:

I. Close-path infrared gas detection (Point devices) measure the amount of gas present at a fixed location.
II. Open path detectors consist of separate transmitters and receivers that detect the presence of gas up to 200 meters away. To give the best level of safety, a combination of open-path and point detectors can be used in most circumstances.

3.7. Flame Ionization

A flame ionization detector (FID) is a scientific device that detects analytes in gas streams. In gas chromatography, it is commonly used as a detector. This is a mass-sensitive instrument since it measures ions per unit of time. Standalone FIDs can be used in stationary or portable instruments for applications such as landfill gas monitoring, fugitive pollution monitoring, and internal combustion engine emissions measurement [11].

3.8. Photo Ionization

The Photo Ionization Detector (PID) is a vapour and gas detector that can detect a wide range of organic compounds. When an atom or molecule absorbs enough light to allow an electron to leave and become a positive ion, this is known as photoionization. An ultraviolet lamp releases photons that are absorbed by the compound in an ionization chamber, and this is how the PID works.

Electrodes collect the ions (atoms or molecules that have gained or lost electrons and thus have a net positive or negative charge) generated during this process. The analyte concentration is determined by the current produced. This method is considered non-destructive since only a small fraction of the analyte's molecules is ionized, allowing it to be used in combination with another detector to validate analytical findings. PIDs are also available in a variety of lamp configurations and compact hand-held versions. Results are almost instantaneous [11].

3.9. Optical Detection

Safety Scan specializes in using optical gas imaging to detect hydrocarbon gas leakage using infrared thermal imaging. Real-time thermal images of gas leakage are provided by highly specialized infrared cameras. Optical emission detection is a relatively new technology that has been developed to identify fugitive gas emissions quickly, accurately, and safely. This technology allows the user to "see" hydrocarbon gas emissions that would otherwise be invisible.

Thermal imaging aids in the precise detection of the leak's source, which is critical for repair efforts. This provides a safer, more effective environment for a variety of industrial applications, enabling engineers to pinpoint the leak's source and size in real-time [11].

3.10. Light Scattering

A detector used in high-performance liquid chromatography (HPLC), ultra-high-performance liquid chromatography (UHPLC), purification liquid chromatography such as flash or preparative chromatography, countercurrent or centrifugal partition chromatography, and Supercritical Fluid chromatography is an evaporative light scattering detector (ELSD) (SFC). It is widely employed for the study of substances that do not easily absorb UV light, such as sugars, antivirals, antibiotics, fatty acids, lipids, oils, phospholipids, polymers, surfactants, terpenoids, and triglycerides, where UV detection may be a limitation. The charged aerosol detector (CAD) is similar to ELSDs, and both come within the destructive detector family. Both compounds that are less volatile than the mobile phase, i.e., nonvolatile and semi-volatile compounds, can be detected using an evaporative light scattering detector (ELSD) [12]. However, these techniques have their strengths and constraints as summarized in table 1.

Table 1

Summary of gas detection techniques, strengths, and weaknesses

S/N	Technique	Mode of Operation	Strengths	Weaknesses
1.	Catalytic Bead sensor	Makes use of elements (beads) with catalytic sensors where resistance-change is directly related to the gas concentration in the surroundings and is displayed in a meter.	Relatively inexpensive, rugged, and has a long shelf-life.	They are non-specific and the beads are susceptible to poisoning compounds.
2.	Thermal conductivity	Makes use of varying temperatures and the difference in transport rate with air as reference.	Simple to design and have a long shelf-life.	They have limited application & cannot detect low concentrations
3.	Colourimeter	Makes use of the difference in the chemical reaction of various gases when exposed to other chemicals.	Low cost and detects varieties of gases. It can also detect low-level concentrations	Has limited shelf life with a low level of accuracy. Also, the “paper tape” used is costly to purchase
4.	Metal Oxide sensor	Makes use of semiconductors. Takes full advantage of the properties of some metal oxides to detect a change in their electrical resistance.	They are rugged, durable, and resistant to many sensor poisons.	They are non-specific and tend to give false alarms. Also, they have less reliability.

Continuation Table 1

5.	Electrochemical sensor	Makes use of electrochemical sensors and electrodes to oxidize or reduce a chemical to create sensors for various gases.	They are portable, durable, and have low power consumption.	The electrolyte is prone to leakage. They have a limited shelf-life and consume more power.
6.	Infrared detection	The detector consists of a source of infrared light, an optical filter to select the proper wavelength, and an optical infrared receiver.		
7.	Flame Ionization	The FID works by detecting ions that are produced during the burning of organic molecules in a hydrogen flame. The number of organic species in the sample gas stream determines how many of these ions are produced.	It is relatively inexpensive to acquire and operate and has low maintenance requirements with rugged construction.	Inorganic compounds and some highly oxygenated or functionalized species are not detectable.
8.	Photo Ionization	When compounds reach the detector, they are assaulted by high-energy UV photons and are ionized when they absorb the UV light, causing electrons to be ejected and positively charged ions to form.	It has a wide range of applications due to its linearity; it also has low maintenance requirements.	It is not suitable for the detection of semi-volatile compounds and does not identify the type of volatile compounds present.
9.	Optical Detection	Uses as well as an optical sensor Lightray are converted into an electrical signal by an optical sensor. This is comparable to the function of a photoresistor.	It has high sensitivity, reliability, and a wide dynamic range. It is also chemically inert and is suitable for remote sensing.	It is subject to environmental disturbance and is relatively pricey. It's also vulnerable to bodily harm.
10.	Light Scattering	It is widely employed for the analysis of chemicals where UV detection is a limitation, such as when the compounds do not absorb UV radiation efficiently.	Good for nonvolatile solutes and are low molecular weight polymer.	It has the potential for a high false alarm rate and must be cleaned daily.

Most of the time, these detectors are set to detect no more than two separate gases. When gas is detected, most gas detectors sound a warning buzzer, while others send an SMS to subscribers. Only a select few make provisions to prevent further gas leakage [2]. While these systems have flaws, their implementation and installation have so far resulted in the saving of lives (both plants and animals) and properties.

4. Smoke Detection System in A Smart Kitchen

A smoke detector is a system that detects smoke as a warning sign of a fire. As part of a fire alarm system, commercial security systems send a signal to a fire alarm control panel, while household smoke detectors, also known as smoke alarms, typically emit a local audible or visual alarm from the detector itself [13]. Smoke detectors can detect smoke either optically (photoelectric) or physically (ionization); they can use either or both methods [14]. Smoking can be detected and therefore discouraged in places where smoking is prohibited using sensitive alarms. In large commercial, manufacturing, and residential buildings, smoke alarms are typically operated by a central fire alarm device that is powered by the building's power with a battery backup [15]. Domestic smoke detectors vary in size from individual battery-powered devices to multiple interconnected mains-powered units with battery backup; with these interconnected units, if one detects smoke, they all go off, even if the power is out in the building. In homes with functioning smoke detectors, the chance of dying in a house fire is cut in half [13]. Ionization and photoelectric (optical) techniques are the two main techniques used in smoke detection, as previously described. Figure 4 shows the various smoke techniques in use. The mode of operation, strength, and constraints of these techniques are summarized in table 2.

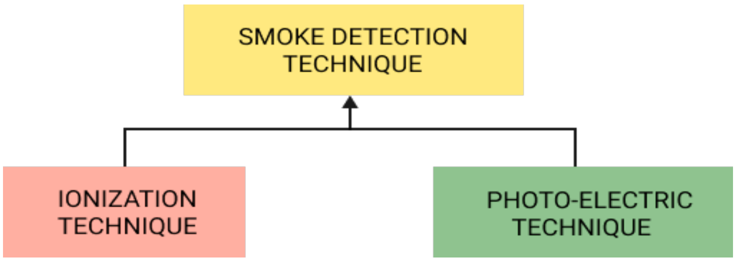

Figure 4. Diagrammatical Representation of Smoke Techniques.

4.1. Ionization Technique

Tiny amounts of radioactive material are present in ionization smoke detectors. Radiation travels through the ionization chamber, which is an air-filled space between two electrodes that allows a slight constant current to flow through them. Any smoke that enters space absorbs alpha particles, reducing ionization and disrupting the current, setting off an alarm. This form of alarm works best in the event of a fast-moving fire. Optical detectors are less sensitive to the stage of fire than ionization detectors [16].

4.2. Photoelectric (Optical) Technique

A light source, a collimated light beam device, and a photoelectric sensor are used in photoelectric smoke detectors. When smoke approaches the optical chamber and travels along the direction of the light beam, the smoke particles disperse a portion of the light, pointing it towards the sensor and triggering the detector. Slow smouldering fires respond better to this sort of warning. Optical detectors are particularly susceptible to fires that are already in the early stages of combustion [16].

Table 2

Comparisons between smoke detection techniques

	A light source, a collimated light beam device, and a photoelectric sensor are used in smoke detectors.	It works well for detecting fires that are swift and blazing. Thanks to its widespread availability, it is still the most common method of smoke prevention.	It is slow in detecting fires with slow properties.
	Makes use of a small amount of radioactive material and electrodes.	Works best in detecting fires characterized by their low properties. Also, a reduced number of false alarms triggered by cooking steam.	Not reliable when checking for fires with high properties.

Using a hybrid solution (ionization and photoelectric) when designing a smoke detector has proved to be more effective. Regardless of the type of detector technique used, the proper positioning and management of the instrument must be taken into account for optimum efficiency.

5. Fire and Fire Detection System in a Smart Kitchen

Fire is one of the most destructive occurrences that can occur; it happens every minute of the day anywhere on the planet. Although fire is always our ally, it may often be our greatest enemy when it is unregulated and left to spread within a structure. Of course, fire is explosive, and smoke from a fire causes a poisonous, hazardous environment [17]. Every year, early warning and containment of fire will save thousands of lives, thousands of deaths, and millions of dollars in property damage. Smoke alarms and warning sensors have been integrated to form life-safety mechanisms in the field of fire detection [5]. An automatic fire alarm system's goal is to detect a fire, warn the control panel and appropriate authority, and advise the occupants to take action.

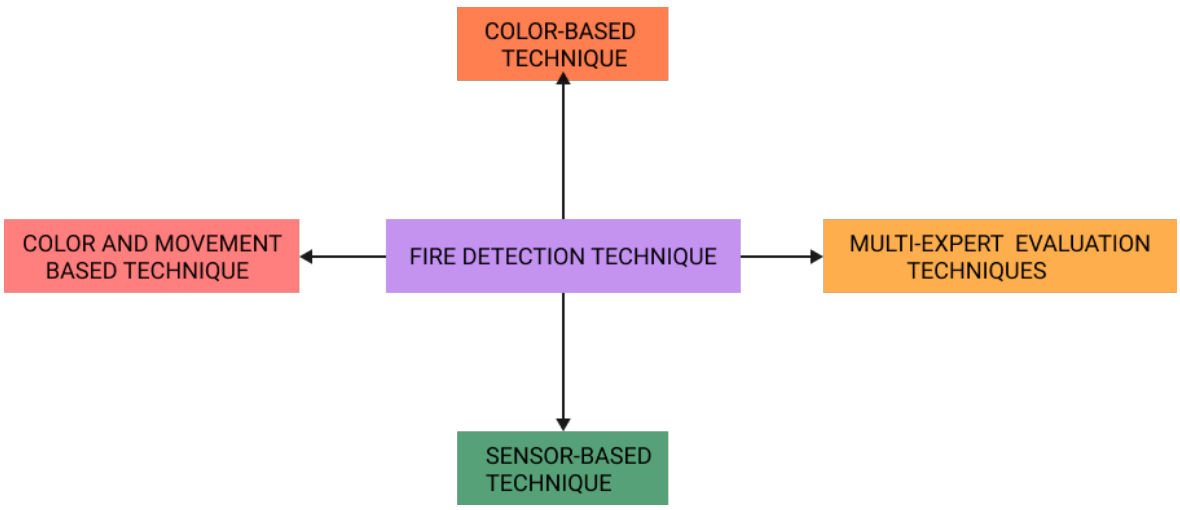

Figure 6. Various Fire Detection Techniques.

A flame detector that uses a sensor to detect and respond to the presence of a flame or fire is used to detect and respond to the presence of a flame or fire. Sound an alarm, shutting off a fuel line (such as a propane or natural gas line), and turning on a fire control device are all possible responses to a perceived blaze, depending on the installation [18]. Figure 6 shows the various techniques for fire detection currently in use.

5.1. Color-Based Fire Detection

The colour of fire pixels is compared to the colour of candidate pixels in colour-based detection. This is achieved on the basis that the fire pixels would be reddish-yellow in colour. The methods that employ these features are based on the premise that flames are created by common materials such as wood, plastic, paper, and other materials. Such that the colour components in RGB (Red, Green, and Blue), YUV (Luminance, Chrominance), or some other colour space will accurately characterize the colour to recognize the existence of flames [15].

5.2. Sensor-Based Fire-Detection Method

Fire detection is critical in a variety of settings, including mines and other industrial settings. As a result, having an alert device capable of detecting fire and sounding an alarm is critical. Sensor-based fire detection methods use sensors to track fire. In general, the use of sensors yields high efficiency in all types of detection processes. The sensors detect features such as fire, light, and other factors to make a decision [15].

5.3. Color and Movement-Based Evaluation

Colour-based assessment will aid in the identification of fire pixels, but it will be less effective in densely populated environments. This is because these pixels are selected solely based on their colour. Some aspects go well with the colour of the flames. It would be more precise if we combine the function of movement with colour-based assessment. This is founded on the fact that the fire pixels would be in a constant state of motion. As a result, it would analyze each frame by comparing it to its previous and subsequent frames. As a result, fire detection will be a little more precise [15].

5.4. Multi-Expert Evaluation

Multi-Expert Evaluation will combine the opinions of many experts and conclude. In the current scenario, it tests each of the characteristics of fire, such as colour, movement, and form, as experts and uses them to detect fire. Because of the special colour of flames, colour is one of the most significant features used. Other elements, such as movement and shape, may be added to increase efficiency. The flame's movement is assessed based on the fact that it is constantly moving in nature, and its form is taken into account since the flame's shape varies every minute seconds. As a result, if we take adjacent pictures, the flame pixels' values will rapidly change. Multi-Expert Systems usually make use of this property [15].

6. Review of Related Works in Gas, Smoke and Fire Detection in a Smart Kitchen Automation System

Several analyses of gas, smoke, and fire detection methods have been published previously, either as academic articles or scientific studies. These efforts have shown to be beneficial in reducing the risk of dangerous effects. This section presents each of these research works, as well as their contributions, achievements, and shortcomings.

Research in [19] created a gas leakage detector for protection and protection using an LPG gas sensor attached to an IoT using an ESP module. The primary controller was an

Arduino. The project's final output was used to detect gas leakage from cylinders and also to alert the consumer through IoT software. It had three major issues, including energy efficiency, localization, and routing; however, the proposed solution is less expensive than currently existing detectors. Research in [20] used the Internet of Things to build a device that eliminates risks in kitchens (IoT). Multiple sensors, a control unit, an alarm buzzer, and a GSM module made up this device. To control a gas leak, this mechanism automatically shuts off (closes) the valve. This machine often controls the cylinder's gas level, and when the device's weight falls below the "fixed point," it immediately schedules the cylinder for a refill from the gas agency. This proposed architecture has a wide range of applications that have proved to be effective and reliable. Research by Adekitan et al. in [21] presented a design that used a pragmatic protection strategy to track and evacuate gas leaks before they fire. A control unit, a buzzer bell, a GSM module, and an actuator are all included. This configuration had the advantage of automatically shutting off the gas supply solenoid valve and evacuating the gas by turning on the evacuator fans. However, since untreated gas leakage will cause actual fire outbreaks, there is no actual countermeasure for an actual fire outbreak. Research by Sharma et al. [17] devised a new approach for detecting fire at an early stage to reduce risk. A control unit (Arduino UNO), an MQ-5 gas sensor to detect a gas leak, a GSM module for mobile communications, a buzzer for warnings, an exhaust fan, batteries, LEDs, and other components are included in the device. The system had safety features such as turning on the exhaust fan to remove gas from the environment. However, it had no provisions for dealing with real fires or explosions caused by the use of expired gas cylinders.

Research by in [16] proposed a multi-sensor solution for a fire warning system prototype. MQ-5 gas sensor, Grove temperature sensor, Grove light sensor, Arduino microcontroller, GSM module, and GPS shield is included. In the event of fire detection and outbreak, the device is configured to transmit alerts to registered contacts. Although it is restricted to residential buildings, this device can identify and distinguish between hazardous and non-harmful smoke. Research in [22] in their paper, suggests a framework that uses the Internet of Things (IoT) to connect multiple physical objects that are embedded with electronics, sensors, and software that can capture data from the environment and transfer it over the internet. This device can be used for a variety of purposes, including defense, agriculture, and more. This system necessitates the deployment of a vast number of sensor clusters for greater reliability. Research in [23] proposed an intelligent smoke detector device the machine used the Random Forest Algorithm to detect smoke, ZigBee Transmission Technology to create a wireless network, E-charts for data analysis, and a smoke detector module to capture environmental data. Temperature, humidity, pressure, and dust sensors are among the sensors employed. The machine makes use of a low-power optimization scheme, but there is no safeguard measure put in place. Research in [24], describes the use of an LPG gas sensor to detect a leak and generate the results in audio and visual formats, as well as alerting humans via SMS (SMS). The sensors used have excellent sensitivity and a fast response time, but no countermeasures are provided for the observed leakage.

Research in [25] with the aid of an Arduino, creates a device that can detect a variety of dangerous gases. This work alters the currently available structures, which are mostly found in commercial settings but can also be used in homes and at work. The LCD detects and displays poisonous gases such as butane (also known as LPG), methane, and carbon monoxide. The percentage concentration of these would be shown on the LCD, but it has a slow reaction time and does not have countermeasures against the detected gas. [26], the design of a gas leakage safety device is the subject of this paper. LPG is highly flammable and can cause a fire even if it is far away from the source of the leak. Most fire accidents are caused because of a poor-quality rubber tube or when the regulator is not turned off. The supply of gas from the regulator to the burner is on even after the regulator is switched off. If the knob is switched on by accident, gas leaks will occur.

The detection, monitoring, and control system for LPG leakage is the subject of the research. The stove knob is operated automatically by a relay DC motor. Along with safety features, the mechanism has the added benefit of automatically rebooking the cylinder when the gas level falls below the cylinder's usual weight. GSM connectivity, on the other hand, is disabled. While [27], their work focuses on the Internet of Things (IoT) connectivity of every sensor to create a smart home. Temperature sensors can also monitor high and low temperatures, allowing the system to identify the temperature and alert the user. The created android application would allow the user to turn on and off the lights manually. This provides a significant benefit to the IoT-based smart home system. [28], also, with the assistance of an Arduino Nano microcontroller, a gas sensor, and an XBee, a gas leakage detection device was suggested. The sensor node can detect a minute concentration of gas based on the voltage output of a sensor and will also capture gas leakage data, allowing the sensor node to be pinpointed to a particular location. A GSM module served as a link between the microcontroller and the mobile phone unit. It has a wide range of applications, such as in petrochemical plants and agricultural factories, but it does not provide any safeguards against detected gases and has a longer response time.

Research in [29], the concept and implementation of an SMS-based Industrial/Homes Gas Leakage Monitoring and Detection Alarm System were presented in this article. The device is designed to deter gas leaks from causing damage or deaths. Hardware and software were designed, developed, configured, and incorporated into the system. When a gas leak is detected, the time it takes for the customer to receive an SMS from the system control unit is often reviewed and tested for accuracy to ensure timely transmission of the system's early warning alert, but it does not have any countermeasure against the detected gas. Research in [30], in his job, developed and introduced a framework to meet the gas leakage health and safety requirements. The suggested device is tested, and the findings are checked, by generating an early warning signal in less extreme conditions and activating a high-pitched alert during LPG leakage to protect consumers. Even though the device is noisy due to the lack of a mechanism to switch off the warning buzzer and no precautionary precautions against detection, the average system cost is smaller and the reaction time is faster. Research in [31], when the concentration value of toxic gases such as carbon monoxide reaches the usual value, the paper developed a system that positions gas sensors in the leak points, which detects the concentration value of toxic gases such as carbon monoxide and imitates to the mobile unit. The signal is sent to the PIC microcontroller, which uses the ZigBee communication module to inform the mobile computer. This architecture has a quick response time, but it is more realistic for large-scale petrochemical applications, so it is limited to petrochemical industries for optimum efficiency. Research by Saeed et al. in [32], A GSM-based gas detector system for propane and butane gases was built in this work, and a GSM module was used to relay messages to the consumer in the event of a leak. The device, on the other hand, has no safeguards against actual detection. In the work of Saeed, [33], using multiple sensors, a wireless sensor network was developed and tested for early fire detection of a house fire. To stop false alarms, GSM was used. Low-cost sensor nodes, temperature, light, and smoke data are spread out around the forest in this device to gather information, which is then fed into ANN models and transformed into knowledge. There is a significant time delay that could endanger human life and property; however, the results produced are correct.

Research by Kusampudi et al. in [34] Using Fuzzy Logic strategies, proposed a device architecture for fire-fighting robots that sense the fire and enter the target area without touching any obstacles, avoiding damage to lives and property. Many ultrasonic sensors installed on the robot sensed the turn angle between the robot head and the target, the distance of obstacles around the robot (front, left, and right, including other mobile robots), and were used as feedback fuzzy members in another contribution. The aim of developing fire-fighting robots is for them to enter a fire area zone without colliding with any obstacles to avoid causing harm in an unfamiliar environment. Despite its high reliability and performance, the net device cost is not cost-effective; therefore, it could be out of reach on average. Research by Sarwar et al. in [35] with the help of Artificial Intelligence Technology Fuzzy Logic, created a simple way to detect fire using multiple sensors instead of a single sensor. In a human way of thought, the built framework was easier to use and was closely similar to the actual model idea. It needs an accurate dataset for optimum efficiency, which could be difficult to obtain, and it has no mode of communication (i.e., GSM module), but it is extremely reliable. Research by Sowah et al. in [36] describes a device for detecting fire in vehicles using an Arduino microcontroller and Fuzzy Logic Artificial Intelligence Technology to prevent any harm to the vehicle caused by fire. When a fire is observed, temperature sensors, flame sensors, and smoke sensors are used. When a fire is detected, a sound detector is activated, and carbon dioxide is sent to the site, causing both environmental and noise emissions. A system is installed and tested in a medium-sized physical vehicle, with a 2 kg cylinder fixed behind the passenger's back seats. Research by Çelik et al. [37] proposed a model for detecting fire and smoke without the use of any sensors in their work, which is focused on image processing. The framework is set up in such a way that colour data and motion analysis are integrated using the derived model. Environmental contamination may cause this system to fail, resulting in inaccurate readings. This method, on the other hand, has improved accuracy. In the intelligent house, Suli et al. [38] built an automatic fire alarm and fire control linkage system. The machine intelligently predicts fire, monitors gas, and has an automated fire alarm and linkage feature, however, there are no countermeasures in place to prevent real leaks and fire outbreaks. Finally, Slavkovikj et al. in [39] Social networking networks are being used to spot fires in the current architecture. According to the author, as the number of social networks and services grows, so does the volume of knowledge that is shared on the internet. The author suggested a web design for wildfire social sensors (WSS). As a result, social media can provide a human-centric sensor network for the early identification of disasters such as fire; however, the optimum efficiency of this architecture is solely dependent on the network's stability.

7. Open Issues and Challenges in Gas Leakages, Smoke, and Fire Detection in A Smart Kitchen Automation System

The critical findings made during the analysis are taken into account. To build an effective detection system in a smart kitchen, precise knowledge of the application is often needed. The reviewed papers contain material that can be used as a foundation upon which a study can begin. It's also important to note that none of these devices can be trusted if their reactions to external factors including gas, smoke, and fire aren't tested regularly. Available systems in today's market face problems such as most conventional home systems are automatic, so they cannot change and respond to the consumers' actual working environmental conditions. Also, according to the poll, certain devices have a high likelihood of causing a false alarm because they are vulnerable to noise and minor variations in the environment's sounds. While these devices sense a fire until it spreads, there is little control or precautionary measures in place, making property loss almost unavoidable. Also, in some designs, multiple sensors were used to increase accuracy, however, it requires large numbers of "clusters" of sensors to be deployed which will inevitably increase overall system cost and deployment cost.

8. Conclusions

This review paper serves as a basic guide to help researchers choose the right technology for gas leakage, smoke, and fire detection in a smart kitchen. A comprehensive survey of several smart kitchen automation systems was performed in this research. Also included is a description of what has been done in this area to date, as well as the research gap and open issues that need to be addressed in this research area. A wide range of gas leakage, fire, and smoke detection systems in a smart kitchen was studied and classified into three main categories: gas leakage detection, smoke detection, and fire detection in a smart kitchen. Finally, the research gaps and unsolved challenges in gas leak detection, fire detection, and smoke detection in a smart kitchen were reviewed. We found that the majority of existing systems are not dynamic, and as a result, they are unable to adapt and react to the user's present operating environment. Furthermore, because some of the systems are sensitive to noise and tiny changes in the environment, they have a high likelihood of generating a false alert.

Conflicts of Interest. The authors declare no conflict of interest.

References

1. Atsushi, H.; Mori, N.; Funatomi, T.; Yamakata, Y.; Kakusho, K.; Minoh, M. Smart kitchen: A user centric cooking support system. In *Proceedings of 12th International Conference on Information Processing and Management of Uncertainty for Knowledge-Based Systems (IPMU 2008)*, Malaga, Spain, June 22-27, 2008, 8, pp. 848-854.
2. Simon, A.; Erameh, K.; Iruansi U. Design and development of kitchen gas leakage detection and automatic gas shut off system. *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS)* 2014, 5(3), pp. 222-228.
3. Diaa, S. A. M.; Abd-ELfattah, M.; Ali M. A. Design of an Internet of Things (IoT) network system for Kitchen food waste management. *International Journal of Computer Science and Network Security (*IJCSNS) 2018, 18(5), pp. 130-138.
4. Ejaz, A. F.; Gurusamy, P.; Kumar, G.; Mahavignesh S. LPG Detection Using GSM Module. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (JAREEIE)* 2016, 5(1), pp. 12-15.
5. Lars, B.; Frantzich, H. Fire alarm in a public building: How do people evaluate information and choose an evacuation exit? *Fire and Materials Journal* 1999, 23(6), pp. 311-315.
6. Andi, A.; Dani, A. W. Design of small smart home system based on Arduino. In *Proceeding of Electrical Power, Electronics, Communicatons, Control and Informatics Seminar (EECCIS 2014)*, Malang, Indonesia, August 27-29, 2014, pp. 121-125.
7. Kontogiannis, T.; Leva, M.; Balfe, N. Total safety management: principles, processes and methods. *Safety science Journal* 2017, 100, pp. 128-142.
8. Poorva, K.; Duggal, P.; Pawar, A.; Bhalerao, M. R. Smart Gas Booking & LPG Leakage Detection System. *International Journal of Advance Research and Innovative Ideas in Education* 2019, 5(3), pp. 825-830.
9. Sunil, P.; Waqar, A. GSM Based Gas Leakage Detection & Prevention System for Disabled and Handicapped. *International Journal of System Modeling and Simulation* 2016, 1(1), pp. 7-10.

10. Kleven, B. A. *Summary of Gas Detection*. 1st edition, Tucson: Arisona, USA, 2007, pp. 1-12.
11. Skoog, D. A.; Holler, F. J.; Crouch, S. R. *Principles of instrumental analysis*. 7th Edition, Sunder College Publisher: New York, USA, 2017; pp. 9-15. Available online: https://www.amazon.com/Principles-Instrumental-Analysis-Douglas-Skoog/dp/1305577213.
12. Douville, V.; Lodi, A.; Miller, J.; Nicolas, A.; Clarot, I.; Prilleux, B.; Megoulas, N.; Koupparis, M. Evaporative light scattering detection (ELSD): a tool for improved quality control of drug substances. *Pharmeuropa scientific notes* 2006, 1, pp. 9-15.
13. Alsaadi, A. Smart smoke and fire detection with wireless and global system for mobile technology. Master Degree Thesis, California State University, Long Beach, January 2016.
14. Alan, W. Smoke alarm detection, broadcast notifications and social implications. Master Degree Thesis, University of Otago, New Zealand, November, 2010.
15. Saylee, G.; Birla, S.; Pandey, S.; Dargad, R.; Pandita, R. Smoke and fire detection. *International Journal of Advanced Research in Computer and Communication Engineering* 2013, 2(6), pp. 2420-2424.
16. Obanda, Z. S. Multi-sensor fire detection system using an Arduino Uno microcontroller. Master Degree Thesis, Strathmore University, Kenya, June, 2017.
17. Sharma, S.; Singh, D.; Rathore, S. S.; Bansal, P. Fire detection system with GSM using arduino. *Imperial Journal of Interdisciplinary Research* 2017, 3(4), pp. 2243-2245.
18. Sivaranjani, S.; Gowdhami, D.; Karthikkannan, P. An appraisal on gas leakage detection and controlling system in smart home using IoT. *Emerging Technologies in Networking and Security (ETNS)* 2016, 7(9), pp. 608-615.
19. Naren, V.; Indrajith, P.; Prabhu, R.; Ganesh, C. Intelligent Gas Leakage Detection System with IoT Using ESP 8266 Module. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering 2018,* 7(12), pp.4157-4161.
20. Anandhakrishnan, S.; Nair, D.; Rakesh, K.; Sampath, K.; Nair, G. S. IOT based smart gas monitoring system. *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)* 2017, pp. 82-87.
21. Adekitan, A. I.; Matthews, V. O.; Olasunkanmi, O. A microcontroller based gas leakage detection and evacuation system. *Materials Science and Engineering* 2018, 413(1), pp 1-7.
22. Shinde, R.; Pardeshi, R.; Vishwakarma, A.; Barhate, N. Need for wireless fire detection systems using IOT. *International Research Journal of Engineering and Technology (IRJET)* 2017, 4(1), pp. 1078-1081.
23. Wu Q., Cao J., Zhou C., Huang J., Li Z., Cheng S. M. and Pan G. Intelligent smoke alarm system with wireless sensor network using ZigBee. *Wireless Communications and Mobile Computing Journal* 2018, 2018 (3), pp. 1-11.
24. Selvapriya, C.; Sathya, P. S.; Abdulrahim, M.; Aarthi K. LPG leakage monitoring and multilevel alerting system. *International Journal of Engineering Sciences & Research Technology* 2013, 2(11), pp. 3287-3290.
25. Katole, K.; Bagade, V.; Bangade, B.; Soni, A.; Kamde, H. Hazardous Gas Detection using ARDUINO. *International Journal of Science Technology & Engineering* 2016, 2 (10), pp. 534-538.
26. Soundarya, T.; Anchitaalagammai, J.; Priya, G. D.; Kumar, S. K. C-leakage: Cylinder LPG Gas leakage Detection for home safety. *IOSR Journal of Electronics and Communication (IOSR-JECE)* 2014, 9(1), pp. 53-58.
27. Mehta, H.; Jadhav, K.; Mishra A.; Deshmukh, A. IOT based home automation system using arduino board. *International Research Journal of Engineering and Technology (IRJET)* 2017, 4(1), pp. 1541-1544.
28. Mujawar, T.; Bachuwar, V.; Kasbe, M.; Shaligram A.; Deshmukh, L. Development of wireless sensor network system for LPG gas leakage detection system. *International Journal of Scientific & Engineering Research* 2015, 6(4), pp. 558-563.
29. Georgewill, O. M.; Ezeofor, C. J. Design and Implementation of SMS-Based Industrial/Homes Gas Leakage Monitoring & Detection Alarm System. *International Journal of Engineering Trends and Technology (IJETT)* 2016, 35(9), pp. 410-416.
30. Gupta, A. Economical and optimal gas leakage detection and alert system. *International Journal of Scientific and Research Publications* 2017, 7(11), pp. 260-263.
31. Ganesh, D.; Bala, A. Improvement on gas leakage detection and location system based on wireless sensor network. *International Journal of Engineering Development and Research* 2015, 3(2), pp. 407-411.
32. Shrivastava, A.; Prabhaker, R.; Kumar, R.; Verma, R. GSM based gas leakage detection system. *International Journal of Technical Research and Applications* 2013, 1(2), pp. 42-45.
33. Saeed, F.; Paul, A.; Rehman, A.; Hong, W. H.; Seo H. IoT-based intelligent modeling of smart home environment for fire prevention and safety. *Journal of Sensor and Actuator Networks* 2018, 7(11), pp. 1-16.
34. Kusampudi, N.; Sanjeev, J. Navigation of autonomous fire-fighting robots using fuzzy logic technique. *International Journal of Engineering Science Innovation and Technology* 2015, 4, pp. 138-147.

35. Sarwar, B.; Bajwa, I. S.; Jamil, N.; Ramzan, S.; Sarwar, N. An intelligent fire warning application using IoT and an adaptive neuro-fuzzy inference system. *Sensors* 2019, 19 (3150), pp. 1-18.
36. Sowah, R.; Ampadu, K. O.; Ofoli, A.; Koumadi, K.; Mills, G. A.; Nortey J. Design and implementation of a fire detection and control system for automobiles using fuzzy logic. In Proceeding of *IEEE industry applications society annual meeting*, Portland, Oregon, USA, October 2-6, 2016, pp. 1-8.
37. Çelik, T.; Özkaramanlı, H.; Demirel H. Fire and smoke detection without sensors: Image processing based approach. In *15th European Signal Processing Conference (EUSIPCO-07)*, Poznan, Poland, September 3-7, 2007, pp. 1794-1798.
38. Suli, W.; Ganlai, L. Automatic fire alarm and fire control linkage system in intelligent buildings. *International Conference on Future Information Technology and Management Engineering (FITME 2010)*, Changzhou, China, October 9-10, 2010, 1, pp. 321-323.
39. Slavkovikj, V.; Verstockt, S.;Van Hoecke, S.; Van de Walle, R. Review of wildfire detection using social media. *Fire Safety Journal* 2014, 68, pp. 109-118.

Citation: Umar, B. U.; Olaniyi, O. M.; Dauda, I. A.; Maliki, D.; Okoro, C. P. Recent Advances in Smart Kitchen Automation Technologies: Principles, Approaches and Challenges. *Journal of Engineering Science* 2022, 29 (3), pp. 150-165. https://doi.org/10.52326/jes.utm.2022.29(3).13.

Submission of manuscripts: jes@meridian.utm.md