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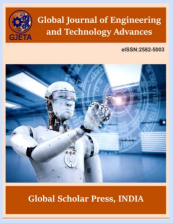

(RESEARCH ARTICLE)

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Multifunctional gas safety monitoring and classification warning device

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Abstract

Due to the absence of automatic flameout and other essential functionalities in these devices, incidents such as gas leaks can easily lead to explosions. As a result, an autonomous safety monitoring and early warning device has been specifically developed for traditional gas stove equipment. This device is capable of activating a multi-tiered alarm and control mechanism when it reaches a predetermined threshold concentration. The main control of the Arduino Uno R3 microcontroller development board serves as the foundation for this device, which utilizes the MQ-5 gas sensor and 1602 liquid crystal display module to provide real-time gas concentration display. It also incorporates a sound and light alarm system that triggers when the concentration exceeds the predetermined threshold. Additionally, it employs a human infrared sensor and flame sensor as modules for fire detection and occupancy monitoring respectively. Any abnormal changes in these parameters will activate the sound and light alarm system. Equipped with an LED light and buzzer, this system provides real-time monitoring around gas stoves. Experimental results demonstrate excellent responsiveness under current conditions. Given its significant relevance in ensuring gas safety, this multifunctional gas safety monitoring device with classification early warning capabilities holds immense potential for market applications.

Keywords: Gas leakage; Hot flames leaving person; Monitoring early warning; Arduino

1. Introduction

Gas, being an immaculate and highly efficient energy resource, offers a plethora of remarkable advantages in both everyday life and industrial production, rendering it widely embraced. However, ensuring the secure utilization of gas in residential settings and industrial operations is of paramount importance. Any occurrence of safety accidents such as gas leakage can result in substantial property damage and casualties[1-5]. Gas stoves, commonly employed equipment in contemporary kitchens that provide unparalleled convenience, also present an array of potential hazards. Particularly with older gas stoves lacking safety protection mechanisms and automatic extinguishing devices, the probability of gas leakage and subsequent accidents including explosions escalates significantly. Furthermore, the protracted utilization of gas stoves can give rise to noxious gases that pose a peril to human well-being.

In the realm of household gas stoves, intelligence is predominantly showcased through flameout protection mechanisms that autonomously sever the gas supply and avert any potential leakage in case of inadvertent extinguishment (e.g., caused by soup overflow or being snuffed out by gusts of wind). Presently available in the market are two primary categories of automatic flameout protection devices for gas stoves [6-8]. The first category encompasses thermocouple-based flameout protection devices which function by regulating solenoid valve actions based on temperature disparities detected by the thermocouple to alter the air supply pathway. The second category comprises ion induction-based flameout protection devices which govern solenoid valve actions via discerning variations in flame ion conductivity to switch the source of air. Each approach possesses its own set of merits and demerits.

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Thermocouples have a tendency to deteriorate over time, potentially leading to premature extinguishment if they fail to reach a specified temperature difference threshold. Moreover, frequent flameouts can also impact their performance adversely. Furthermore, thermocouple-based systems exhibit longer response times and lower technical sensitivity compared to ion induction-based counterparts. Although ion induction devices offer the advantage of promptly responding even when natural winds slightly displace flames away from their sensors without causing complete extinguishment, they may still trigger the closure of gas sources, necessitating re-ignition.

Currently, the prevailing intelligent gas stoves in China are predominantly equipped with NTC active heat source tracking technology. This cutting-edge technology astutely detects the state of dry burning by precisely measuring and sensing the temperature at the bottom of the pot. With its highly sensitive response, it promptly activates the protection device within approximately one minute upon detecting a dry burning state, effectively shutting off the gas supply and extinguishing any flames. However, relying solely on automatic cut-off valve technology often falls short in completely eradicating gas stove accidents as flammable and toxic gases can accumulate in the air during prolonged periods of being turned off.

The primary focus of this paper is to investigate a versatile gas safety monitoring and classification warning device system based on Arduino hardware and software. The system comprises two main components: the gas leakage monitoring module and the active fugitive monitoring and classification warning module. This design utilizes the Arduino Uno R3 development board along with its supporting modules for assembly design. Key sensors include the MQ-5 gas sensor, 1602 LCD display, flame sensor, human infrared sensor, LED light, and buzzer. The gas leak monitoring module employs the Arduino microcontroller as its core in conjunction with a series MQ-5 gas sensor module. It is also equipped with a 1602 liquid crystal display for real-time tracking of gas concentration. Furthermore, it incorporates an LED tube and buzzer for early warning and alarm functions. Similarly, by employing the Arduino single chip microcomputer as its core, the fire sensor and human infrared sensor are connected in series to monitor the dynamic relationship between flames and humans in real time.

1.1. Monitoring and early warning system working principle

After the activation of the monitoring system, it continuously and dynamically monitors the real-time gas concentration. Simultaneously, the 1602 LCD screen displays the instantaneous gas concentration in a synchronized manner. In case the gas concentration falls within the normal range, the system functions flawlessly. However, if it surpasses a critical threshold, an immediate audible and visual alarm will be triggered to promptly remind users to ensure proper ventilation. Furthermore, this sophisticated system evaluates both flame presence and personnel status: (presence of flame with individuals) or (absence of flame but presence of individuals).

If a flame persists without any human presence for more than 2 minutes, it signifies the potential existence of an unattended fire. In such instances, the system activates resplendent sound and light alarms until an individual materializes before its sensors; only then does it cease the alarm and proceed to monitor at the subsequent level. Similarly, in cases where neither flame nor person is detected, it implies that the flame has inadvertently extinguished itself. The system responds by issuing resounding sound and luminous alarms until someone reappears and duly terminates them. Once all levels of monitoring ascertain that safety conditions are met, cyclic monitoring resumes as per usual.

The comprehensive connection diagram comprises of an Arduino Uno R3 development board, an MQ-5 gas sensor, a 1602 LCD display, a human infrared sensor, a flame sensor, an LED light, and a buzzer [9-12]. The MQ-5 gas sensor is exceptionally suitable for monitoring liquefied natural gas, natural gas, and city gas in both household and industrial settings. It exhibits remarkable sensitivity towards these gases while displaying minimal responsiveness to ethanol and smoke. Furthermore, it showcases robust anti-interference capabilities and rapid response recovery. Notably, this sensor boasts an extended service life with reliable stability. Additionally, the test circuit associated with this sensor is relatively straightforward.

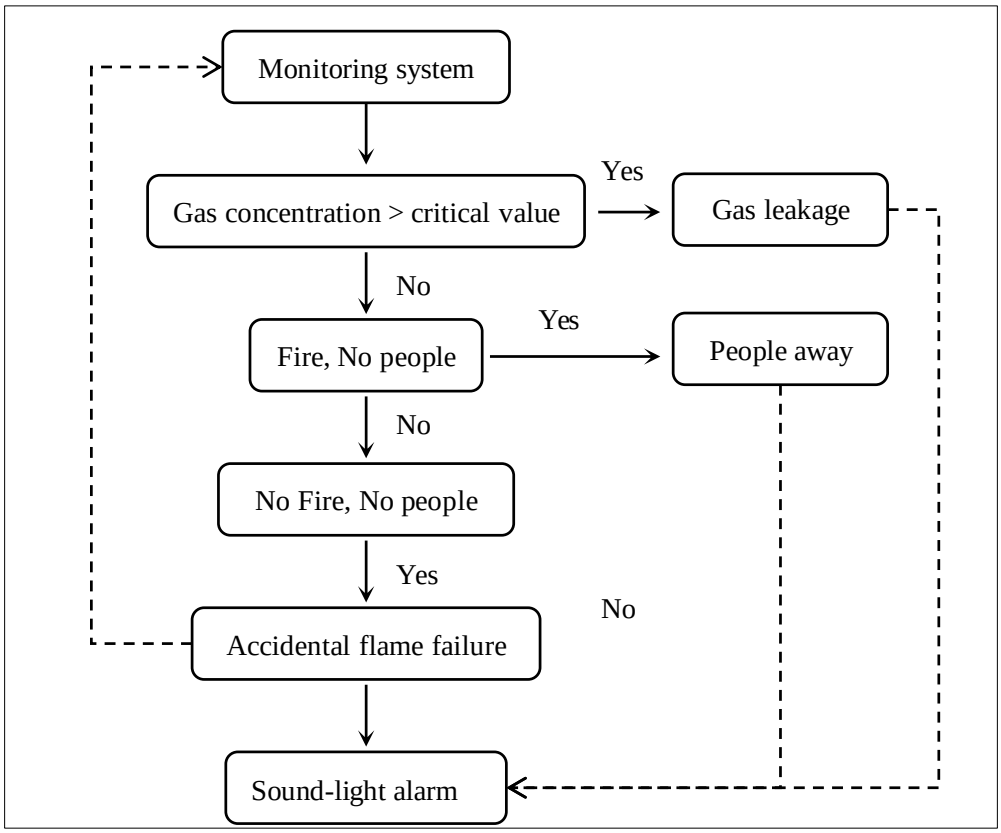

Figure 1 Flowchart of the Multi-functional Gas Safety Monitoring and Gradual Warning Device

Figure 2 MQ-5 gas sensor

The HC-SR501 human infrared sensor possesses the remarkable ability to detect and perceive the infrared radiation emitted by humans or animals, thereby generating electrical signals in response. By harnessing the invisible heat emanating from the human body, this sensor exhibits exceptional sensitivity in capturing even the most subtle fluctuations in body temperature. It promptly reacts to movements of the human body, producing corresponding signal outputs when approached or moved away from. Equipped with automatic induction, this sensor module instantaneously emits a high level output upon detecting someone within its range. Similarly, after a certain delay period once the person exits the detection range, the output automatically transitions to a low level.

Figure 3 The HC-SR501 human infrared sensor

The flame sensor is a highly efficient device that relies on the use of infrared photodiodes to accurately detect and measure emitted infrared radiation from heated objects. By utilizing this advanced technology, it ensures reliable and precise detection of flames in various applications. One key feature of the flame sensor is its ability to compare the detected radiation against a pre-established threshold value. This allows for real-time adjustments of its output signal once the threshold level is reached, ensuring prompt response and appropriate action can be taken when flames are detected.

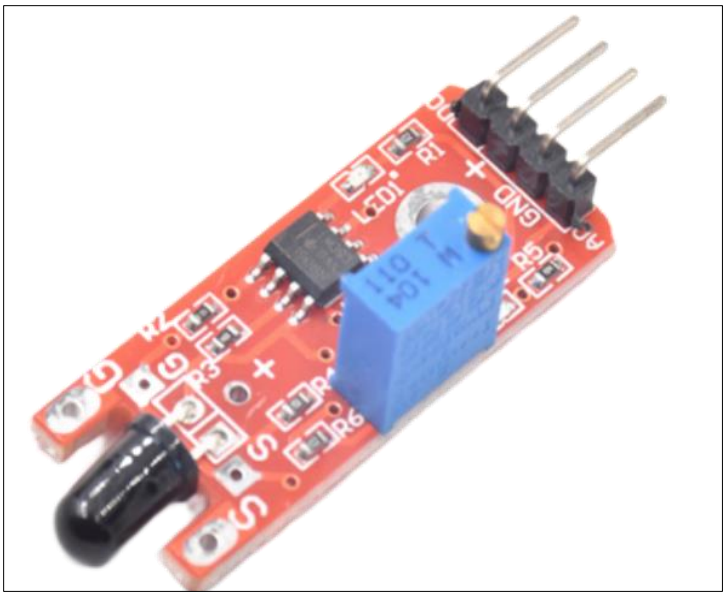

Figure 4 Flame sensor

Operating within a wavelength range spanning from 700 nm to 1000 nm, the flame sensor covers a wide spectrum of infrared radiation. This broad range enables it to effectively capture emissions from different heat sources, making it versatile for diverse environments. Additionally, the flame sensor boasts an expansive detection angle of 60 degrees. This wide field-of-view enhances its capability to identify flames across larger areas or multiple directions simultaneously. It provides comprehensive coverage and minimizes blind spots, increasing overall safety measures in fire detection systems.

It should be noted that external levels of incident infrared illumination have an inverse influence on the measured parameter. When there are heightened intensities of incident infrared illumination, such as strong ambient light or other heat sources nearby, they correspondingly yield diminished readings on the flame sensor's measurements. On the other hand, attenuated levels result in augmented measurements as less interference affects accurate flame detection.

1.2. Design of multifunctional gas safety monitoring and classification warning device

The gas concentration surrounding the gas stove serves as an indicator of its stability. However, accidents often occur because users are unaware of gas leakage, leading them to continue operating incorrectly and resulting in explosions. Therefore, by integrating the MQ-5 gas sensor and 1602 liquid crystal display, real-time visualization of the gas concentration around the gas stove can be achieved. This feature is of immense significance for the monitoring module dedicated to detecting gas leaks. Expanding on this topic, it is crucial to emphasize that safety should always be a top priority when using any type of fuel-burning appliance like a gas stove. Gas leaks can pose serious risks not only to property but also to human lives. The integration of advanced technologies such as the MQ-5 gas sensor and 1602 liquid crystal display provides an effective solution for addressing these potential dangers.

With real-time visualization capabilities, users can now have immediate access to information about the concentration levels of gases surrounding their stoves. This allows them to take prompt action if there is any indication of a leak or abnormality in order to prevent accidents from occurring. Furthermore, this integrated system offers convenience and peace of mind for users who may not possess extensive knowledge or experience in dealing with potential hazards associated with using a gas stove. By providing clear visual feedback on the current state of air quality around their stoves, individuals can make informed decisions regarding ventilation or shutting off their appliances if necessary. Moreover, this technology has broader implications beyond individual households. It can be particularly useful in commercial kitchens where multiple stoves are used simultaneously and where constant monitoring becomes even more critical due to higher risks involved.

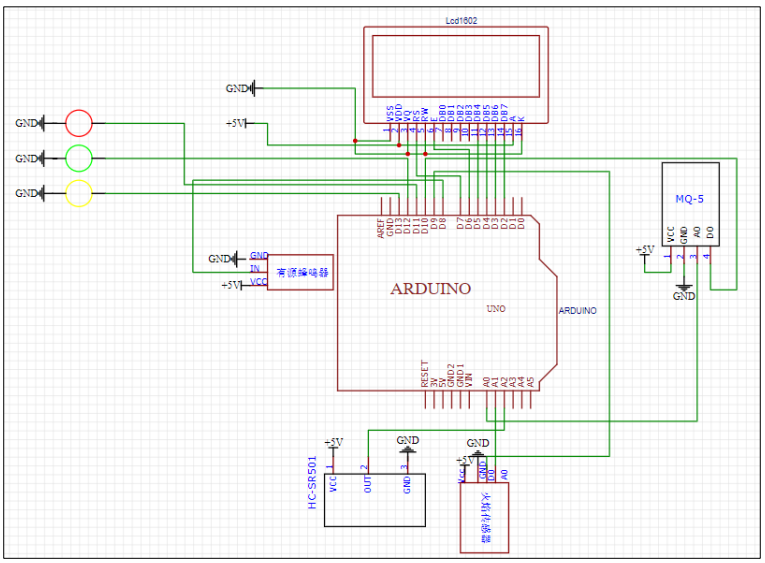

Figure 5 Monitoring and early warning system connection diagram

In addition to monitoring the gas concentration, it is also crucial to ensure the safety of individuals nearby. For this purpose, a human body infrared sensor has been selected as a reliable method for detecting human presence in close proximity to the stove. The infrared sensor is capable of accurately sensing any movement or activity within its range. When there is no activity detected by the infrared sensor, it will activate an audible and visual alarm system as a precautionary measure. Under normal circumstances when there is regular activity detected by the infrared sensor, such as cooking or cleaning in close proximity to the stove, the system operates without triggering any alarms. This ensures that users can go about their daily activities without unnecessary interruptions while still maintaining awareness of their surroundings. By combining both real-time visualization of gas concentration and detection of human presence nearby, this integrated monitoring module provides comprehensive safety measures for users operating around a gas stove. It not only alerts users about potential dangers but also empowers them with knowledge and awareness necessary for safe operation in their kitchen environment.

The flame sensor has been chosen as the primary method for monitoring the presence of flames due to its high accuracy and reliability. By utilizing advanced technology, this sensor is able to detect even the smallest flicker of a flame, ensuring prompt detection and response in case of a fire hazard. In order to provide comprehensive safety measures, a fire-free monitoring module has been developed. This module consists of a microcontroller, which acts as the brain of the system, processing data from various sensors and making real-time decisions. Additionally, it includes a human body infrared sensor that detects any movement or presence near the gas stove area. Working collaboratively with these sensors is the flame sensor itself. Its main function is to continuously monitor for any signs of flames or ignition sources near the gas stove. With its precise detection capabilities, it can quickly identify potential fire hazards and trigger appropriate actions such as sounding an alarm or activating automatic fire suppression systems. Moreover, this integrated system not only focuses on detecting flames but also individuals near the gas stove area. The human body infrared sensor plays a crucial role in identifying any person's presence within close proximity to prevent accidents caused by unintentional contact with hot surfaces or open flames. By combining these technologies together into one cohesive unit, this monitoring system ensures enhanced safety measures for households using gas stoves. It provides reliable and accurate detection capabilities while minimizing false alarms that could lead to unnecessary panic or disruption in daily activities. Overall, through careful selection and integration of different sensors working collaboratively within this monitoring module, both flames and individuals near gas stoves can be effectively detected and monitored for increased safety precautions against potential fire hazards.

This alarm system includes illuminating a green LED light and emitting an alarm sound at a frequency of 1000 Hz. These signals serve as clear indications that there might be potential danger present if someone were to approach or operate near the stove. The purpose of this advanced safety feature is to ensure the well-being of individuals in the vicinity of the stove. By promptly alerting them through both visual and auditory cues, it provides an immediate warning that something may be amiss. The activation of the green LED light serves as a visual reminder for people to exercise caution and remain vigilant. Moreover, emitting an alarm sound at a frequency of 1000 Hz ensures that it can easily catch attention without being too disruptive or overwhelming. This specific frequency has been carefully chosen based on its ability to cut through ambient noise while still being distinguishable from other common sounds in our environment. By incorporating these measures into the design, users are empowered with valuable information about potential dangers associated with approaching or operating near the stove when no activity is detected. It encourages responsible behavior by reminding individuals to assess their surroundings before taking any actions that could potentially lead to accidents or injuries. Overall, this comprehensive audible and visual alarm system acts as a reliable safeguard against unforeseen hazards in kitchen environments where stoves are commonly used. Its presence not only enhances safety but also promotes awareness among users, fostering a culture of proactive risk management and prevention.

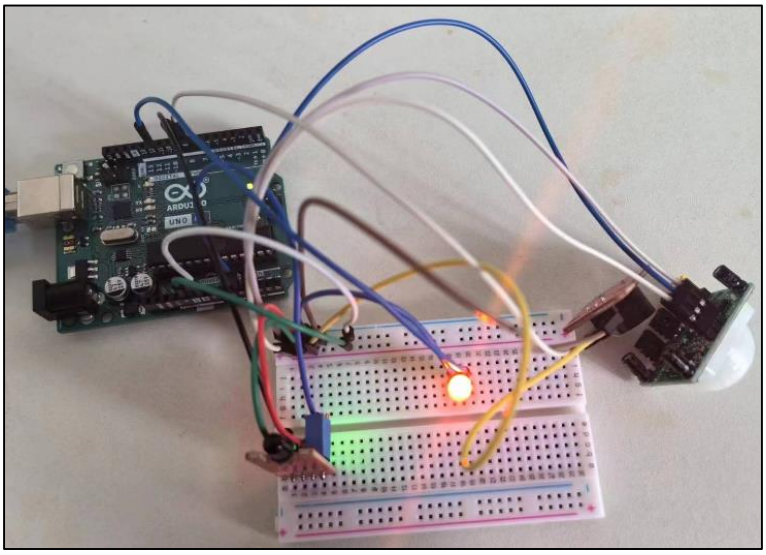

Figure 6 Physical wiring effect drawing

The sound and light alarm system is an essential component in maintaining a safe environment by effectively alerting individuals present at the site. This comprehensive system comprises various elements such as LED lights, buzzers, microcontrollers, and sensors that work together seamlessly. When these highly sensitive sensors detect any hazardous or abnormal conditions within the vicinity, they immediately trigger an automatic mechanism. This mechanism activates intense flashing lights accompanied by high-pitched sounds that are impossible to ignore. The purpose of this

prompt is to ensure swift action from personnel in order to guarantee personal safety and protect valuable property. The LED lights incorporated into the alarm system are designed to emit bright flashes that can be seen even in low-light or dark environments. The sound and light alarm system plays a crucial role in ensuring safety by providing timely reminders to personnel present at the site. It encompasses LED lights, buzzers, microcontrollers, and sensors. When hazardous or abnormal conditions are detected by these sensors, an automatic triggering mechanism activates intense flashing lights accompanied by high-pitched sounds to prompt immediate action from personnel in order to ensure personal safety and protect property. Overall, this advanced sound and light alarm system provides a reliable means of alerting personnel about potential dangers on-site promptly.

1.3. System function test and evaluation

The risk of gas leaks requires the preparation of a lighter to simulate gas leakage and approach the gas sensor. The corresponding code should be written into the Arduino, and the sensor pins should be connected. Upon uploading the code, real-time readings of gas concentration can be obtained. The readout will display "Gas:" on the LCD screen. When initially set up, it will display "Gas:" with a normal range for gas concentration between 48-59, indicated by showing "Normal" on the second line. If the lighter is ignited and brought close to the gas sensor module, there will be a brief illumination of a red LED light for one to two seconds along with a 3000Hz frequency alarm from the buzzer. On this occasion, if the gas concentration value exceeds 60, it will display "Gas:" on line one and show "Alert" on line two. Ceasing ignition of the lighter and keeping it away from the gas sensor results in a gradual decrease in gas concentration levels. The alarm persists until concentrations drop below 60 when it automatically stops sounding off. Actual test results were found consistent with expected outcomes.

The presence of a flame is simulated by operating the lighter and positioning it in close proximity to the flame sensor, creating a realistic scenario. This simulation is enhanced by incorporating human infrared sensors, accurately replicating situations involving flames without any individuals present. In such cases, the serial port monitor will indicate the presence of an individual. According to the code settings, when both the lighter is activated and positioned near the flame sensor module while simultaneously detecting someone through the human infrared sensor, a safe state is established where no sound or light alarms are triggered. However, if one moves out of range from the sensor while keeping the lighter on and close to the flame sensor for more than two minutes, this condition prompts activation of a green LED light along with an audible alarm emitting at 2000 Hz frequency from a buzzer. Upon re-entering within detection range and identifying an individual through sensory input, both audible and visual alarms cease accordingly. The actual test results closely align with initial expectations.

Similarly, a lighter is utilized and positioned in close proximity to the flame sensor to simulate the presence of a flame. In conjunction with the human infrared sensor, it simulates a scenario where there is no flame and no individual present. Based on the programmed code, when the lighter is activated and brought near the flame sensor module, if the human infrared sensor detects someone, it remains in a secure state without triggering any sound or light alarms. However, if you move out of range from the sensor while keeping the lighter turned on and close to the flame sensor, abruptly turning off the lighter indicates that the flame was unintentionally extinguished rather than deliberately closed. In this situation, both yellow LED light illuminates and an audible alarm at 1000Hz frequency is emitted by the buzzer. Upon re-entering within range of detection by the sensor and detecting an individual again, both audible and visual alarms cease accordingly. The actual test outcomes align with our initial expectations.

2. Conclusion

The present design report offers an elaborate account of the intricate process involved in designing and implementing a multifunctional early warning system, meticulously crafted to detect gas leaks emanating from antiquated kitchen stoves. This groundbreaking system seamlessly integrates fire detection capabilities with foolproof escape mechanisms, thereby aiming to substantially mitigate the perils associated with kitchen safety incidents. Arduino has been judiciously selected as the principal control board for this avant-garde system, while two monitoring modules have been ingeniously devised employing MO-5 gas sensors, human infrared sensors, and flame sensors as their quintessential components. By ensuring unwavering precision in monitoring and lightning-fast response times without compromising on cost-effectiveness, this cutting-edge system proficiently issues timely warnings and visually exhibits hazardous gas concentrations during anomalous scenarios such as fires or gas leakage stemming from outdated kitchen stoves. Once the predetermined perilous concentration threshold is reached, the alarm system promptly springs into action to guarantee personal safeguarding.

After the successful completion of system construction and debugging, it has been verified that the system impeccably fulfills the design requirements. The monitoring range effectively encompasses residents' daily kitchen operations with

exceptional sensitivity. Moreover, an alarm buzzer is ingeniously employed to augment man-machine interaction. In terms of innovation: (1) The system is elegantly simple and autonomous, effortlessly operable, and can be seamlessly installed without any alteration to the original structure of new gas equipment while incorporating safety monitoring and protection functions; (2) It proficiently resolves safety hazards such as fires occurring remotely from individuals due to outdated gas stoves or gas leakage; (3) Precise detection is accomplished through multiple sensors operating independently without any interference. The developed system in this design holds profound implications for preventing gas leakage and enhancing citizens' awareness of safety.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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