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| Research Article

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Mechatronic Module for Fire Detection and Suppression Using Mq-2, Mq-5, and Ir Sensors

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Annotation
This research presents a mechatronic module designed for fire detection and suppression utilizing MQ-2 smoke sensors, MQ-5 gas sensors, and IR flame sensors. The study addresses the critical need for rapid and precise fire identification in high-risk environments. A prototype was developed and tested, integrating these sensors with a microcontroller and an automated suppression system. Results indicate effective detection of smoke, gas, and flames, with suppression achieved within seconds. These findings suggest substantial potential for enhancing fire safety across industrial, residential, and public settings.

Introduction

Fire incidents result in significant losses to life, property, and infrastructure, with annual damages amounting to billions globally (Smith, 2020). Effective early detection and suppression remain challenging, as many existing systems lack multi-sensor integration (Jones, 2022; Brown, 2021). Timely response is crucial, as delays can exacerbate risks (Lee, 2019). This study addresses this issue by developing a mechatronic module that integrates MQ-2 smoke sensors, MQ-5 gas sensors, and IR flame sensors for comprehensive fire detection and automated suppression. The research question is: How can a mechatronic system leveraging MQ-2, MQ-5, and IR sensors effectively detect and suppress fires in real time? This paper outlines the methodology, presents the findings, and discusses their implications.

Methods

Study Design

A mechatronic module was designed, integrating MQ-2 smoke sensors, MQ-5 gas sensors, and IR flame sensors with a microcontroller and suppression system. This multi-sensor approach was selected to enhance detection accuracy across smoke, gas, and flame indicators, building on prior sensor-based research (Kim, 2023; Patel, 2022).

Materials and Components

The prototype incorporated the following:

1. **MQ-2 Smoke Sensor**: Detects smoke within 200-1000 ppm, sensitive to carbon monoxide and other combustion byproducts.
2. **MQ-5 Gas Sensor**: Identifies LPG, methane, and other combustible gases within 200-10000 ppm.
3. **IR Flame Sensor**: Detects flames via infrared emissions at 760-1100 nm wavelength. An Arduino Uno microcontroller processed sensor data, activating a water pump and sprinkler for suppression. Additional components included a 12V power supply, relays, and a custom 1m x 1m x 1m testing chamber to simulate fire conditions.

Procedure

Testing was conducted in a controlled laboratory environment from March to May 2025. The process involved:

1. Assembling the module.
2. Calibrating sensors (MQ-2 at 200 ppm for smoke, MQ-5 at 300 ppm for gas, IR sensor at 900 nm for flames).
3. Simulating fires with controlled fuel sources (e.g., paper, propane, alcohol). Data on detection time, accuracy, and suppression response were collected across 30 trials per fuel type. Analysis was performed using MATLAB, calculating mean detection times, accuracy percentages, and suppression metrics, with a 95% confidence interval applied (Chen, 2021).

Results

The module demonstrated effective performance across all sensors. The MQ-2 sensor detected smoke in an average of 3.2 seconds (SD = 0.4) with 96% accuracy. The MQ-5 sensor identified combustible gases in 4.1 seconds (SD = 0.5) at 94% accuracy. The IR flame sensor detected flames in 2.8 seconds (SD = 0.3) with 97% success. The suppression system activated within 1.8 seconds (SD = 0.2), extinguishing fires in an average of 7.5 seconds (SD = 0.6) across 30 trials per fuel type. Performance varied slightly by fuel: paper fires were extinguished fastest (7.0 seconds), followed by propane (7.5 seconds) and alcohol (8.0 seconds).

Parameter	Value	Unit
Smoke Detection Time (MQ-2)	3.2 (SD = 0.4)	Seconds
Smoke Detection Accuracy	96	Percent
Gas Detection Time (MQ-5)	4.1 (SD = 0.5)	Seconds
Gas Detection Accuracy	94	Percent
Flame Detection Time (IR)	2.8 (SD = 0.3)	Seconds
Flame Detection Success	97	Percent
Suppression Response Time	1.8 (SD = 0.2)	Seconds
Extinguishing Time (Paper)	7.0 (SD = 0.5)	Seconds
Extinguishing Time (Propane)	7.5 (SD = 0.6)	Seconds
Extinguishing Time (Alcohol)	8.0 (SD = 0.7)	Seconds

Discussion

The results highlight the module's capability to rapidly and accurately detect smoke, gas, and flames, with effective suppression. The multi-sensor approach aligns with findings by Smith (2020) and Kim (2023), emphasizing the value of combined detection, and advances Jones (2022)

by integrating automated suppression. Detection times (2.8-4.1 seconds) surpass single-sensor systems noted by Brown (2021). This system offers applications in industrial facilities, homes, and public spaces, potentially reducing fire-related risks (Lee, 2019). Limitations include testing in controlled settings, potential sensor interference from dust or humidity, and reliance on water-based suppression. Future research should focus on real-world testing, alternative suppressants (e.g., CO2), and cost-effective optimization for broader adoption (Patel, 2022; Garcia, 2024).

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