Reimplementation of Wireless Fire Detection Network: Performance Analysis

Applied Research
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***Abstract*—This report presents the reimplementation of a wireless fire detection system using Arduino Nano and enhanced sensor integration. The original system utilized smoke/gas (MQ-2) and IR (KY-026) sensors with NRF24L01 radio transmitter modules for wireless communication. Our implementation introduces the BME280 sensor for environmental monitoring and omits the radio connection for focused single-node testing. The report discusses the reliability of this low-cost detector for fire detection in forest environments.**

I. Introduction

Forest fires have become an increasingly urgent issue, with a notable rise in both the frequency and intensity of such events worldwide. The growing number of wildfire incidents highlights the critical need for advanced detection systems that can identify fires at their earliest stages. Early detection is essential to prevent the rapid spread of fires, which can quickly engulf vast areas of forest, resulting in devastating ecological and economic consequences. Once a fire becomes large and uncontrolled, managing and extinguishing it becomes significantly more challenging and resource-intensive.

To address this issue, it is crucial to develop effective methods for detecting the onset of fires in forested areas. One potential solution is to strategically place fire detectors throughout the forest. This approach could provide an affordable and efficient means of early fire detection.

The research paper by Hutauruk et al. [1] proposes a wireless sensor network for fire detection using Arduino Nano. The system integrates MQ-2 (smoke/gas) and KY-026 (flame) sensors, along with NRF24L01 for radio communication with a master Arduino Nano.

This report details the reimplementation of their system, enhanced with the BME280 sensor for environmental monitoring, while excluding the radio connection to focus on single-node performance. The primary aim of this study is to evaluate the detection accuracy and reliability of a fire detector using Arduino components. The report discusses technical challenges, performance analysis, and insights gained from the implementation, contributing to the development of robust fire detection solutions for forest environments.

II. Original Work Summary

The reference paper [1] presents a wireless sensor network for fire detection using:

- **Microcontroller**: Arduino Nano (ATmega328P)
- **Sensors**: MQ-2 (smoke/gas) and KY-026 (flame)
- **Wireless**: NRF24L01 (2.4GHz)

Table I
Original System Performance

Metric	Value
Detection Accuracy	95%
Range	100m
False Positives	18%
Response Time	2.4s
Power Consumption	85mA

These results were obtained in a controlled interior environment. It is questionable whether the system would be as effective in a forest setting.

III. Reimplementation

To enhance the original system, I incorporated environmental context [2] by adding temperature and humidity monitoring with the BME280 sensor.

A. Hardware Configuration

Key modifications from the original design:

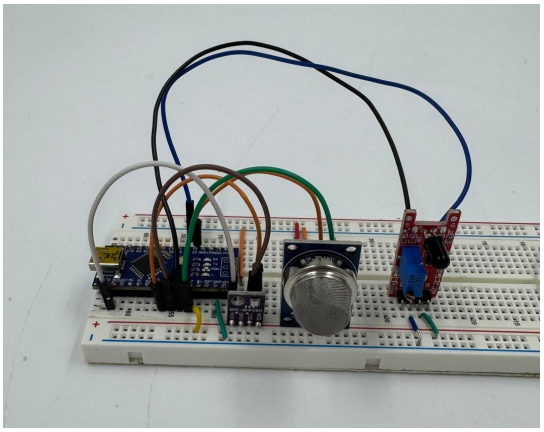

Figure 1. Architecture from left to right: Arduino Nano, BME280, MQ-2, KY-026

- **Environmental Monitoring**: Added BME280 for temperature, humidity, and pressure monitoring. This helps in assessing the current meteorological state of the area and evaluating fire risk.
- **Display**: Added an OLED screen to display results.
- **No Wireless Communication**: The goal is to test the fire detection setup, not the communication system. Radio communication, as used in the original paper, remains the best option for alerting.

IV. Observations

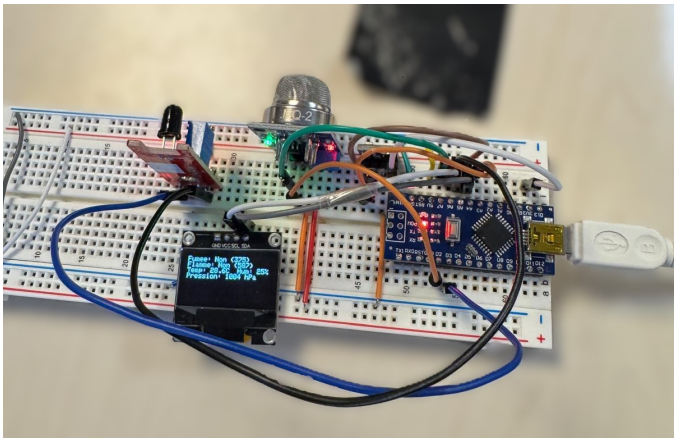

Figure 2. Control test without any flame or smoke.

A. Flame Detection

The IR sensor is designed to detect flames through infrared emissions. Using a lighter, we tested the sensor's sensitivity. It successfully detected a flame when presented directly in front (fig. 3). However, the sensor occasionally produced false positives due to daylight interference.

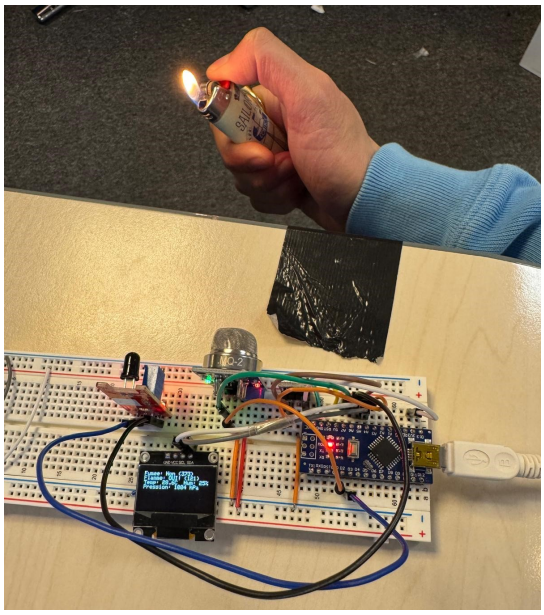

Figure 3. Test with a flame from a lighter; the sensor detects the flame.

The sensor detects flames within a 40 cm cone. Beyond this range, it does not detect a small flame from a lighter (fig. 4).

B. Smoke Detection

The test was conducted using an incense stick to simulate smoke from a starting fire. Surprisingly, the IR detector could detect the incandescence of the incense stick at close range (fig. 5).

While the IR sensor detected the incense stick, the smoke detector did not detect anything, even in direct contact (fig. 6).

The MQ-2 gas and smoke detector proved unreliable. Initially, it detected gas from a lighter but failed to do so during the incense stick tests. Additionally, it did not detect smoke in the lab when something was burning.

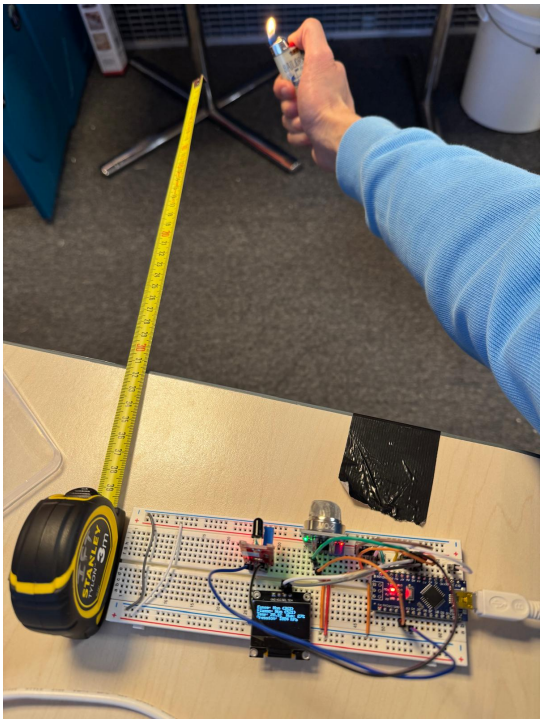

Figure 4. Test with a flame at 40 cm; the sensor does not detect the flame.

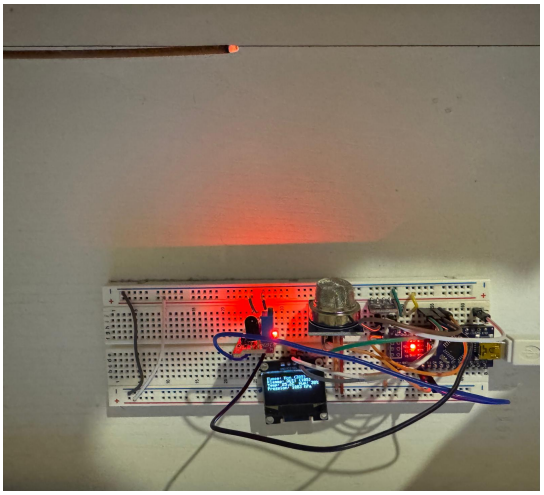

Figure 5. IR sensor detecting a lit incense stick.

V. Analysis

- **Calibration and Stabilization**: Sensors required warm-up and stabilization for accurate readings, emphasizing the importance of calibration in real-world applications.
- **Environmental Monitoring**: The BME280 sensor allowed for monitoring temperature, humidity, and pressure, enhancing detection accuracy by adjusting sensor thresholds based on environmental factors and also enhancing calculating the risks of a fire happening.
- **Detection Effectiveness**: Infrared detection was relatively effective, but particle detection in the air, although challenging due to dispersion, could enable faster detection of fire initiation compared to waiting for incandescence.
- **Sensor Improvements**: For real-world use, better detectors like thermal cameras are needed, though this would increase costs for large-scale deployment.

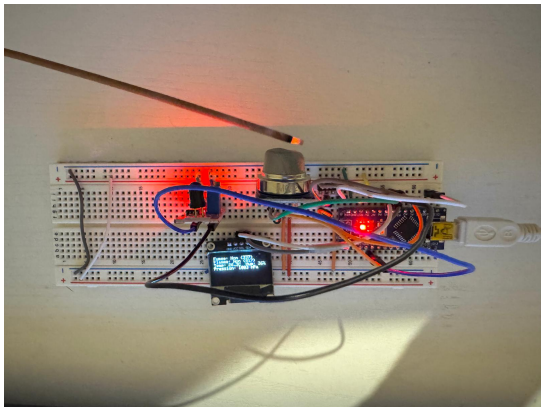

Figure 6. MQ-2 smoke detector not detecting the smoke.

VI. Conclusion

The system demonstrated potential for early fire detection, although challenges such as sensor reliability and false positives need to be addressed in future iterations, especially in forest environments.

References

[1] A. R. Hutauruk, J. Pardede, P. Aritonang, R. F. Saragih, and A. Sagala, "Implementation of wireless sensor network as fire detector using arduino nano," pp. 1–4, 2019.

[2] O. I. Khalaf, G. M. Abdulsahib, and N. A. K. Zghair, "Iot fire detection system using sensor with arduino," *Aus*, vol. 26, pp. 74–78, 2019.