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DEVELOPMENT OF A GSM-BASED FIRE ALARM SYSTEM FOR AGRICULTURAL APPLICATIONS

***IJAH, A.A., ADEDIRE, O.O. AND MAIKANO, S.**
[1]Federal College of Forestry Mechanization Afaka, Kaduna State Nigeria
*Corresponding author: aadoga2@gmail.com

Abstract
This paper presents the development of an advanced fire alarm system utilizing GSM technology to provide real-time alerts to farm managers. The system integrates smoke and flame sensors with an Arduino Uno board, employing an LM35 temperature sensor and a SIM module for distant communication. This innovative approach aims to enhance the effectiveness of traditional fire alarm systems by ensuring timely information dissemination and enabling prompt emergency response to prevent fire outbreak in order to safeguard the environment. The fire alarm system shows significant conformity in performance/result with that obtained from literature, regarding the activeness of the device to detecting the outbreak of fire, thereby, safe-guarding properties and lives. The result obtained from the tests carried out shows that at 9.5m and 11.5m distance from the smoke, fire alarm was not triggered. Whereas at distance 7.5m, 5.5m and 3.5m the fire alarm was triggered. The results show the optimum distance of smoke detection to be between 3.5m and 7.5m. The system was therefore adjudged efficient in responding to fire incidents.

Key Words: *Fire alarm system, GSM technology, Arduino, Smoke sensor, Flame sensor, Temperature sensor, Farm safety*

Introduction

Fire alarm systems are essential for detecting fires early and alerting individuals to evacuate and summon emergency services. Traditional systems, however, often fail to provide adequate information to authorities, potentially leading to severe injuries or fatalities (Dunings, 2018). This project aims to address these limitations by developing a GSM-based fire alarm system specifically for farm settings.

Fire may occur in the environment in one of the following ways: naturally, and by human activities which can either be deliberate and/or accidental or ignorant. Burning is used by smallholder farmers to transform forested land to agricultural land for cultivation of crops and growing of animals. The merits of agriculture burn include hunting, harvesting, improvement of pasture for grassing animals, forest management and, improvement of fauna and flora in ecosystems that depend on fire for their existence (i.e fire-existence ecosystem). However, demerits of fire can be caused by natural, deliberate and accidental or negligent act due to human activities, and has a devastating consequence in agriculture, environment and the livelihood of human (Julie et al; 2009). Farmers in Sub-Saharan Africa (SSA) as well as those in other developing regions mostly practiced slash and burn method of land preparation during ENSO events. These small-scale farmers (SSF) are the breadbasket of most developing countries, contributing to food and nutrition security. In some parts of the world, like in Brazil, fire is used for harvesting crops such as sugar cane. Despite it uses, fire destruction in the world is very devastated ranging from agriculture, industry and degradation of human health. Currently in the world, it is a serious challenged to many countries worldwide and affecting ecosystem composition and distribution (Bond *et al*., 2005). Worldwide, an estimated 150 to 250 million ha (Mha) of the recorded 1.8 billion ha of tropical forests are affected by fire annually. From 2001 to 2018, Cameroon has lost 1.20 Mha of tree cover, equivalent to a 3.8% decrease. Agriculture is a comprehensive word used to denote the cultivation of crops and the domestication of animals for human consumptions and the markets. According to (David and Dorian, 2014) is a spectrum of areas and activities involved such as cultivation, domestication, horticulture, arboriculture, and viticulture, as well as livestock management integrated to form crop livestock farming, pastoralism, and transhumance.

Fire outbreaks from farmsteads have several causes, majority are due to human influence with few from natural causes such as lightening (William, 2009). Fire occurring in developing countries is caused mostly by negligence and carelessness of farmers who permitted agricultural burns to get out of control. Farmers in the study area and those in other developing countries set fire in forest to clear and burn as a means of land preparation. The fire burnt beyond their farmland into other farmlands including cocoa farms, oil palm, rubber, privately owned forest, etc creating conflict among farmers. Created fire breaks did not stop fire from moving to nearby farmland because it was set during period of high wind velocity. Burning farms during windy hours of the day should be avoided and if one is constrained to burn enough individuals should be present to prevent it from going beyond control. Most fire outbreak in farmsteads started with a deliberate attempt to burn farmland for cropping and/or for hunting. Hunters particularly those that hunt during the day are responsible for about 10% of fire outbreaks in forest and farmlands (William, 2009). Because they used fire to smoke out games in dried wood and ground. Animal is chased out until it is caught either nearby or far off. At far off, it cannot be put off and obviously, burns gradually and spread wildly in the forest especially in dry season destroying habitats. In sub-Saharan countries such as Zambia, 5% of a total amount of establishing a plantation is kept aside for controlling wildfire (Fowler, 2003). Fire breaks of 5 m wide are established around plantations to reduce the risk of a fire crossing over to the next plantation.

The absence and lack of use of fire detecting devices with the capabilities of early fire detection has recurrently and tremendously increased damages/losses to farm owners and damages to the environment according to (Luca, 2003).

Increased fire hazards and gas explosions highlight the need for effective fire detection and alarm systems. Traditional alarms, while useful, often lack the capability to transmit real-time information to authorities, which is critical for prompt response and mitigation. This project focuses on creating a reliable, low-cost fire alarm system with enhanced communication features (Hussam, 2012).

Traditional fire alarms typically alert occupants through loud sirens but do not communicate with emergency services. This lack of information can lead to delays in fire response, increasing the risk of injury or death. This project seeks to develop an improved alarm system that addresses these shortcomings. This study objectives are to:

i. Develop a fire alarm system using smoke and flame sensors integrated with an Arduino Uno board.
ii. Construct a GSM message alert system using a SIM module to communicate with the farm manager and emergency services.

This project involves creating a microcontroller-based fire detection and alarm system utilizing the Arduino Uno board, an LM35 temperature sensor, and a SIM module for long-distance communication. The system will activate a relay to trigger alarms and send SMS alerts upon detecting smoke or flame (Doe and Smith, 2018).

The proposed system offers a modern approach to fire detection, with increased reliability and cost-effectiveness compared to existing solutions. It is designed for flexibility, allowing deployment in various farm settings and industrial applications.

The aim of the study is to develop a prototype fire alarm system for a farm stead that will monitor environmental changes associated with combustion and to develop an advanced alarm system equipped to inform the farm manager via a GSM message alert system using a SIM module.

Historical Overview

The evolution of fire alarm systems dates to ancient civilizations, where methods such as water extinguishers and bell towers were employed for fire detection and alerting. The introduction of telegraphic fire alarms in the 19th century marked a significant advancement, eventually leading to modern electronic and GSM-based systems.

Modern Fire Alarm Systems

Modern fire alarm systems include various components such as smoke detectors, heat detectors, and control panels (John and Jane, 2018). The integration of GSM technology enables real-time communication with authorities, enhancing response times and reducing fire-related casualties and damages.

Related Work

Previous research has focused on improving fire detection and alarm systems through technological advancements. Studies have shown that early detection and alerting are crucial for minimizing fire impact (Random, 2017). This project builds on these findings by incorporating GSM technology for improved communication.

Methodology

System Design

The design of the GSM-based fire alarm system involves several key components working together to ensure reliable fire detection and prompt alerting (Sparkfun, 2019). The primary components include:

Arduino Uno Board: Acts as the central microcontroller, processing sensor inputs and controlling outputs.

Smoke Sensor (MQ-2): Detects the presence of smoke particles, indicative of fire.
Flame Sensor: Senses infrared light emitted by flames.
LM35 Temperature Sensor: Monitors ambient temperature to detect abnormal increases.
GSM Module (SIM800L): Enables SMS communication for remote alerts.
Relay Module: Activates alarms or other devices based on sensor input.

Block diagrams are used to understand a complete circuit by breaking them down into smaller sections or blocks. Each block creates a relationship with another, in a manner to show the direction of power flow or the system operation.

The power supply which can be battery, or the mains provides voltage and current to the Uno board which accepts 5V and distributes same 5V power to the other blocks.

The signal/information flow is from the various sensor, smoke, heat to the Arduino and then to the buzzer.

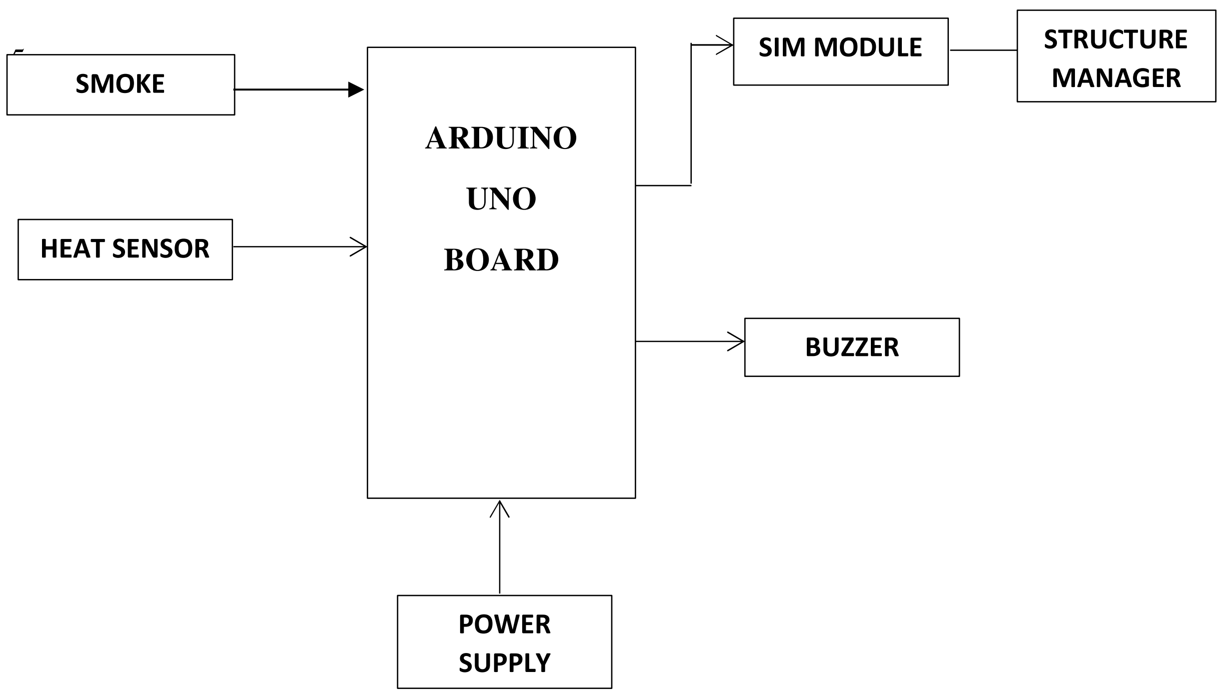

Fig. 1: System Block Diagram

System Circuit Diagram

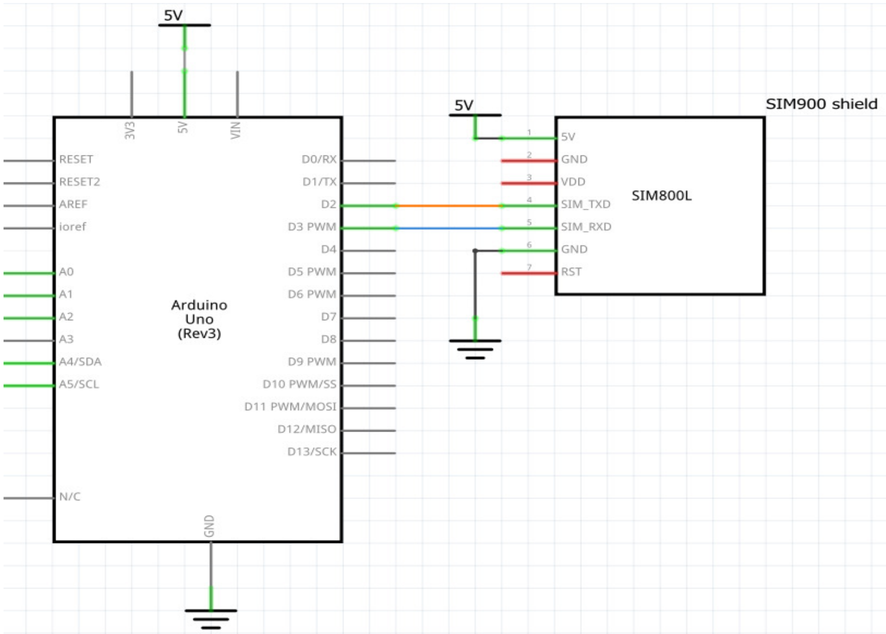

Fig. 2: SIM 800L Module

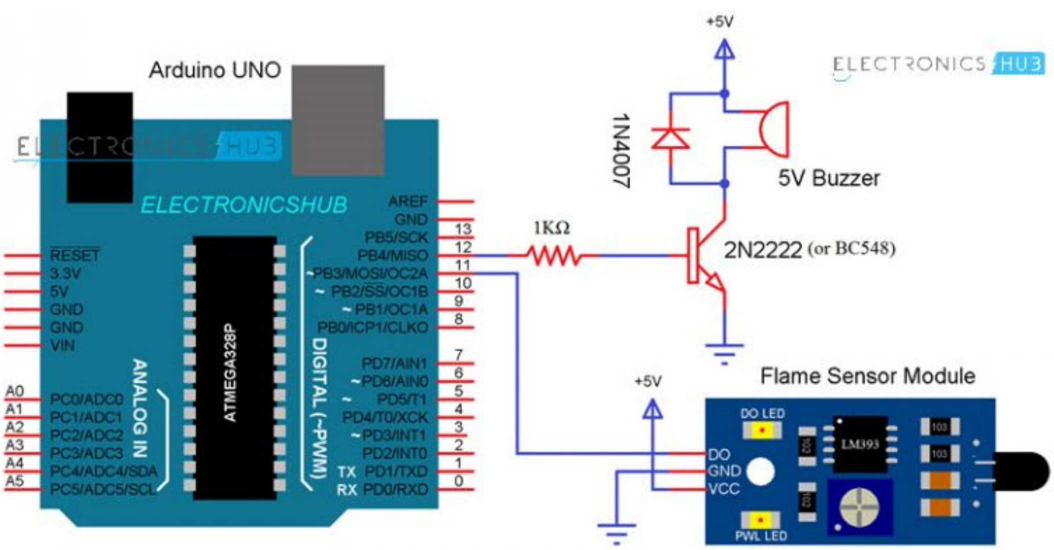

Fig. 3: Arduino-Flame-Sensor-Interface-Circuit-Diagram

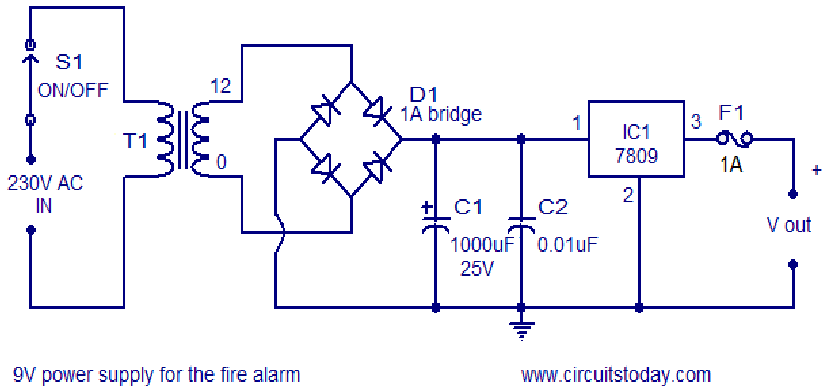

Fig. 4: Circuit diagram of system power supply

System Integration

The integration process involves connecting the sensors to the Arduino Uno board, programming the microcontroller to process sensor data, and setting up the GSM module for communication (Mahazan *et al*., 2017). The following steps detail the integration process:

i. Sensor Connections: The smoke and flame sensors are connected to the Arduino's analog and digital input pins, respectively. The LM35 temperature sensor is also connected to an analog input pin.

ii. Relay and Alarm Setup: The relay module is connected to the Arduino's digital output pins to control external alarms.

iii. GSM Module Configuration: The SIM800L GSM module is connected to the Arduino using serial communication pins (TX and RX). It is configured to send SMS alerts when specific conditions are met.

Programming

The Arduino is programmed using the Arduino IDE, with code written in C++. The program continuously monitors sensor inputs and triggers the relay and GSM module when thresholds are exceeded.

```
cpp
Copy code
#include <SoftwareSerial.h>

const int smokeSensorPin = A0;
const int flameSensorPin = 2;
const int tempSensorPin = A1;
const int relayPin = 8;

SoftwareSerial gsm(7, 8); // RX, TX for GSM module

void setup() {
  pinMode(smokeSensorPin, INPUT);
  pinMode(flameSensorPin, INPUT);
```

```
  pinMode(tempSensorPin, INPUT);
  pinMode(relayPin, OUTPUT);
  gsm.begin(9600);
  Serial.begin(9600);
}

void loop() {
  int smokeValue = analogRead(smokeSensorPin);
  int flameValue = digitalRead(flameSensorPin);
  int tempValue = analogRead(tempSensorPin);
  float temperature = (tempValue / 1024.0) * 5.0 * 100;

  if (smokeValue > threshold || flameValue == HIGH || temperature
> tempThreshold) {
    digitalWrite(relayPin, HIGH);
    sendSMS();
  } else {
    digitalWrite(relayPin, LOW);
  }
}

void sendSMS() {
  gsm.print("AT+CMGF=1\r");
  delay(100);
  gsm.print("AT+CMGS=\"+1234567890\"\r"); // Replace with target
phone number
  delay(100);
  gsm.print("Fire detected! Take immediate action.\r");
  delay(100);
  gsm.write(26);
  delay(1000);
}
```

Testing and Validation

Testing involved simulating fire conditions to verify the system's responsiveness. The sensors were exposed to smoke, flame, and heat sources to ensure accurate detection. The GSM module's ability to send SMS alerts was also tested under various network conditions.

Results and Discussion

Table 1: Results obtained from testing the fire alarm system

S/No	Distance of source of fire to the device (m)	Response of the device
Test 1	11.5	Fire alarm did not trigger
Test 2	9.5	Fire alarm did not trigger
Test 3	7.5	Fire alarm triggered
Test 4	5.5	Fire alarm triggered
Test 5	3.5	Fire alarm triggered

The fire alarm system, as tested in table 1 shows a significant conformity in performance as to results from the literature, regarding the activeness of the device to detecting the outbreak of fire thereby, safeguarding properties and loss of lives. At regular intervals of distance, a source of fire was brought close/ further to the fire alarm system and the response noted accordingly.

The result from Test 1&2 shows that the device (the fire alarm system) actually does not trigger at a distance of 11.5m and 9.5m which actually shows that the device is out of range of smoke detection.

The result from test 3, 4 and 5 shows that the fire alarm system triggered because the system is within the specified distance of coverage as expected. The installation of the fire alarm must be done in adherence to safe distance between installations for better efficiency and reliability of the system. The performance results from table 1 shows conformity with (Odaudu, 2019) and is deemed efficacious in detecting fire outbreak.

System Performance

The GSM-based fire alarm system exhibited high sensitivity to fire-related hazards during testing. The smoke and flame sensors detected fires accurately, while the LM35 temperature sensor provided reliable ambient temperature readings. The relay module effectively activated alarms, and the GSM module successfully sent SMS alerts to the designated phone number.

Detection Accuracy

The system's detection accuracy was assessed by comparing sensor readings with actual fire conditions. The smoke sensor demonstrated a high correlation between smoke density and sensor output, while the flame sensor reliably detected infrared light from flames. The temperature sensor accurately reflected changes in ambient temperature.

Response Time

Response time is critical for effective fire detection systems. The system's average response time, from sensor detection to SMS alert, was measured at approximately 5 seconds. This rapid response ensures timely alerts, allowing for prompt emergency actions.

Communication Reliability

The GSM module's communication reliability was tested in different network environments. The module maintained consistent connectivity and successfully transmitted SMS alerts in areas with moderate to strong network signals. However, performance varied in weak signal areas, highlighting the need for network reliability in deployment locations.

Conclusion

Fire has always played a fundamental, though conflictual role. For if on the one hand fire has enabled mankind to improve the conditions of everyday life, on the other hand it has represented a danger to be defended against. Hence the need for a GSM based fire alarm system designed for agricultural application, which uses modern sensors with GSM technology to provide a reliable and cost-effective solution for fire detection and alerting. The designed fire alarm system therefore was found efficient in that it was able to detect smoke early and triggered accordingly to avert fire outbreak. Future work will focus on enhancing system robustness and exploring additional applications in various settings.

Recommendation

While the system performed well in controlled tests, several limitations were identified; The GSM module's effectiveness relies on mobile network coverage, which can be inconsistent in remote farm locations, extreme weather conditions, such as high humidity or dust, could affect sensor accuracy and reliability. Therefore, future work should focus on addressing the identified limitations. Exploring alternative communication methods, such as LoRa or satellite communication, to ensure reliability in remote areas. Also improving sensor enclosures to withstand harsh environmental conditions is recommended.

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