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Fire Safety Model: An Efficient Real-Time Fire Detection And Alert System

Dhruv J. Patel[1], Prachi P. Patel[2]
Prof.Bhavik H. Prajapati[3], Prof.Divya H. Rami[4]
[1,2] B.Tech student, 3,4Assistant Professor,
[1,2,,3,4] ICT Department, Sankalchand Patel College of Engineering, Visnagar, India[4]
Email - [1]djpatel1457@gmail.com, [2]patelprachi7945@gmail.com, [3]bhavik.digielectro@gmail.com, divyarami14@gmail.com[4]

Abstract: *Fire hazards pose significant threats to life and property, making early detection and timely alerts critical in reducing the damage caused by fire incidents. This research paper a Fire Detection and Alert System that utilizes a combination of sensors and communication modules to detect fire, identify the location of the incident, and immediately alert concerned authorities via SMS and phone calls. The system is built using an IR sensor for flame detection, an Arduino microcontroller for processing, a GSM module for sending SMS alerts and making calls, and a gsm Neo-6M module for providing real-time location data of the fire. Once a flame is detected, the system sends an SMS containing the exact coordinates of the fire to predefined contacts and triggers a call alert to ensure immediate attention. This system is designed for efficiency, offering low-cost and reliable fire detection, making it ideal for applications in homes, offices, and industrial environments. The results from testing demonstrate quick response times and accurate location tracking, proving the system's effectiveness in providing rapid fire alerts. Future enhancements could include integration with cloud services for remote monitoring and extending the system's functionality with additional sensors like smoke or temperature sensors.*

Keywords*: Fire detection, IoT, Arduino, GSM modual , GPS modual , Infrared Sensor.*

1. INTRODUCTION:

Fire hazards are a serious threat to life and property, and the importance of early detection cannot be overstated. Fires, if not detected in time, can escalate quickly and cause immense damage. Traditional fire detection systems often rely on manual triggers or delayed alarms, which can lead to late responses in critical situations. Therefore, there is a growing need for advanced fire detection systems that can not only detect fires promptly but also provide real-time alerts to ensure immediate action is taken. This research paper focuses on developing a Fire Detection and Alert System that combines the capabilities of sensors and communication modules to provide an efficient and real-time solution. [1,4] The system is designed to automatically detect fire using an infrared (IR) sensor and instantly notify the relevant authorities or individuals through SMS and phone call alerts. It also includes a GPS module that provides the exact location of the fire, enabling faster response times. The core of the system is built using an Arduino microcontroller, a GSM module for SMS and call notifications, a GPS Neo-6M module for location tracking, and a buzzer to provide local alarms. When the IR sensor detects a flame, the system triggers an alert, sending the location coordinates to pre-set emergency contacts, ensuring prompt action can be taken. This research paper is not only aimed at improving fire safety but also at providing a cost-effective, reliable, and easily deployable solution. The system can be used in homes, offices, factories, and other environments where fire safety is a priority. With a focus on real-time alerting and location tracking, this system bridges the gap between detection and response, potentially saving lives and minimizing property damage. [6,21]

2. TOOLS AND TECHNOLOGY:

The smart fire safety model utilizes various technologies to detect fire incidents, send alerts, and provide real-time location tracking for effective emergency response.

A. Sensor Technology

Infrared (IR) Senso:

- Working Principle: The IR sensor detects the presence of fire by identifying infrared radiation emitted by flames. It consists of an IR LED (emitter) and a photodiode (receiver) When a flame is present, the sensor detects the infrared light and triggers an output signal.
- Applications: Used in fire detection systems, motion detection, and proximity sensing.
- The IR sensor helps detect flames efficiently and send signals for further processing.

B. Communication and Alert System

GSM Module (SIM800L/SIM900A):

- Working Principle: The GSM module enables mobile communication by connecting to cellular networks. It allows sending SMS alerts and making calls when fire is detected.
- Key Features:
  - Supports SMS and voice call functions
  - Operates on 2G networks
  - Requires a SIM card to function
- It provides real-time fire alerts by sending SMS messages with location details and making emergency calls.

C. Real-Time Location Tracking

GPS Module (NEO-6M):

- Working Principle: The GPS module uses satellite signals to determine precise geographical coordinates. It processes signals from multiple satellites and calculates location data.
- Key Features:
  - High sensitivity and accuracy
  - Supports UART communication with microcontrollers like Arduino
  - Provides latitude and longitude data
- To send the exact location of the fire incident in SMS alerts.

D. Control and Processing Unit

Arduino Board (Uno/Nano):

- Working Principle: Arduino is a microcontroller board that processes sensor inputs and controls output devices based on programmed instructions.
- It integrates all components (IR sensor, GSM module, GPS module, and buzzer) and runs the programmed logic for fire detection and alerting.

3. METHODOLOGY:

Developing the fire safety system involves several steps and stages, including planning, designing, development, testing, and deployment. The process of developing this system requires an understanding of fire detection methods, selecting appropriate sensors, and integrating communication technologies for real-time alerts.

System Design: A system design is produced based on the acquired requirements. This includes defining the system architecture, selecting communication protocols, and choosing the appropriate hardware and software platforms. The system consists of an IR sensor for fire detection, an Arduino board for processing, a GPS module for location tracking, and a GSM module for sending alerts.

Sensor Selection and Placement: This step involves choosing and placing sensors strategically to ensure accurate fire detection. An Infrared (IR) sensor is used to detect flames based on infrared radiation. The sensor is positioned in a way that maximizes fire detection coverage. Proper calibration is performed to minimize false positives.

Development: After the system design is finalized and sensors are placed, the development phase begins. This involves programming the Arduino microcontroller to process sensor inputs and trigger alerts. The GSM module is programmed to send SMS notifications with real-time location data obtained from the GPS module. The buzzer is

integrated to provide an immediate on-site alarm. Hardware components are connected, and software logic is implemented to ensure seamless communication between devices.

Testing: The testing phase is essential to ensure that the system functions as expected. The system is tested under different fire conditions to evaluate the accuracy of the IR sensor and the efficiency of alert transmission. The GPS module is tested for precise location tracking, and the GSM module is verified for successful SMS and call functionality. Any issues encountered are resolved through debugging and recalibration.

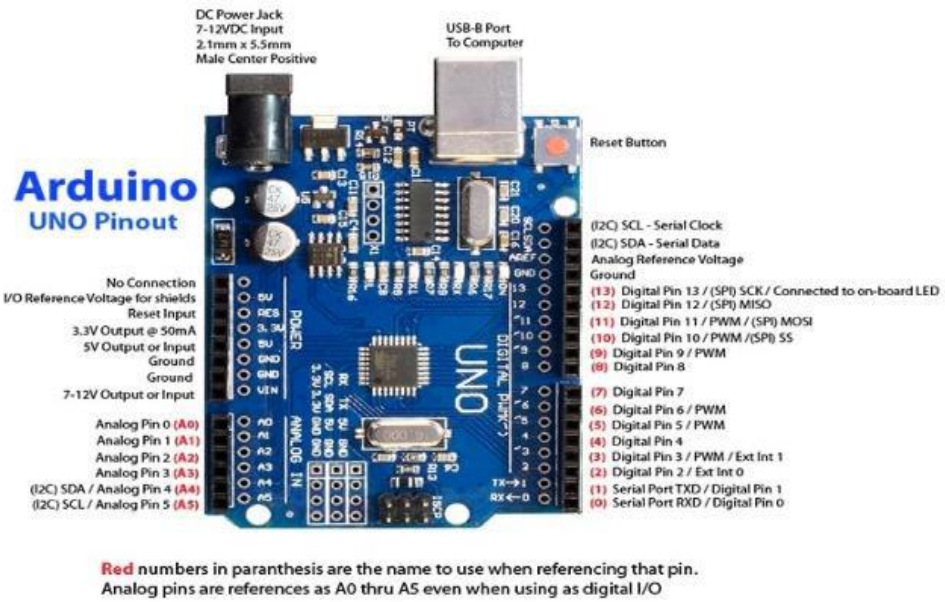
Deployment: After successful testing, the system is ready for deployment. The fire detection module is installed in the desired location, and all components are securely connected. The GSM module is activated with a valid SIM card for network connectivity. The system operates autonomously, continuously monitoring fire incidents and providing real-time alerts to designated contacts.

Overall, developing this fire safety system requires a multidisciplinary approach, including expertise in sensor technology, microcontroller programming, communication systems, and embedded hardware integration. The final implementation ensures an efficient and real-time fire detection and alerting solution.

- Hardware Component Of Fire Safety Model

1) Arduino uno: The Arduino UNO is a popular microcontroller board based on the ATmega328P chip, widely used in electronics projects and embedded systems. It features 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, and a reset button. The board is easy to program using the Arduino IDE, which supports simplified C/C++ programming. In this research paper, the Arduino acts as the central processing unit, responsible for reading data from the IR sensor and GPS module, processing this data, and triggering the buzzer and GSM module when fire is detected. It continuously monitors the environment through sensors, fetches location coordinates from GPS, and sends alerts via GSM in case of emergency. Arduino UNO supports both serial communication with external modules and real-time processing, making it suitable for sensor-based automation projects. Its compact size, open-source flexibility, and low cost make it ideal for prototyping and real-time applications. In this system, Arduino plays a vital role in coordinating hardware and executing programmed logic to ensure accurate and quick fire detection and alerting. The Arduino UNO is shown in below Fig.4.1. [7,19]

Fig.3.1 Arduino UNO



2) IR sensor or Flame sensor:

An Infrared (IR) sensor is an electronic device that detects infrared radiation emitted by objects, making it useful for fire detection applications. It operates based on the principle that flames emit infrared light, which can be detected by the sensor's photodiode. The IR sensor consists of two main components: an IR emitter (LED) that emits infrared light and an IR receiver (photodiode) that detects reflected or emitted infrared radiation. When a fire occurs, the sensor identifies the infrared radiation and generates an electrical signal, which is then processed by a microcontroller like Arduino.

The IR sensor is highly sensitive to flame radiation, allowing it to detect fire even from a distance. It works efficiently in various environmental conditions, although it may be affected by ambient infrared sources like sunlight or hot objects. To improve accuracy, filtering techniques and threshold adjustments are applied. The sensor typically operates at a wavelength of around 760 nm to 1100 nm, which is within the near-infrared spectrum.

IR sensors are widely used in fire alarm systems, security systems, and industrial safety applications due to their fast response time and low power consumption. They are also cost-effective and easy to integrate with microcontrollers, GSM modules, and other alert systems. In this research paper, the IR sensor plays a crucial role in detecting fire at an early stage, triggering the GSM module to send SMS alerts and activating a buzzer for immediate warning. The IR sensor is shown in below fig.4.2 . [10]

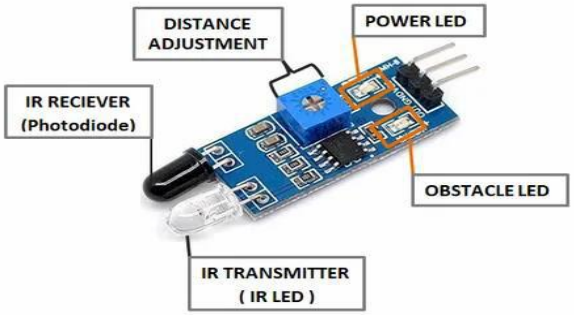


Fig.3.2 IR Sensor

3) GSM Module: A GSM (Global System for Mobile Communications) module is a communication device that allows microcontrollers to send SMS messages, make calls, and connect to mobile networks. It operates using a SIM card, similar to mobile phones, and communicates via 2G, 3G, or 4G networks, depending on the module type. In this research paper, a SIM800L/SIM900A module is used to send real-time fire alerts via SMS when the IR sensor detects a fire. The module communicates with Arduino using AT commands through serial communication (UART protocol). It requires a stable power supply (3.7V–4.2V) and an antenna to ensure proper signal reception. The GSM module is widely used in IoT, remote monitoring, and emergency alert systems due to its reliability and long-range communication capabilities. In case of fire, it sends an SMS containing fire alerts along with GPS coordinates for accurate location tracking. The module is compact, cost-effective, and easy to integrate with embedded systems. Its ability to provide real-time alerts makes it a crucial component of this fire safety system. The GSM modual is shown in below fig.4.3. [8]

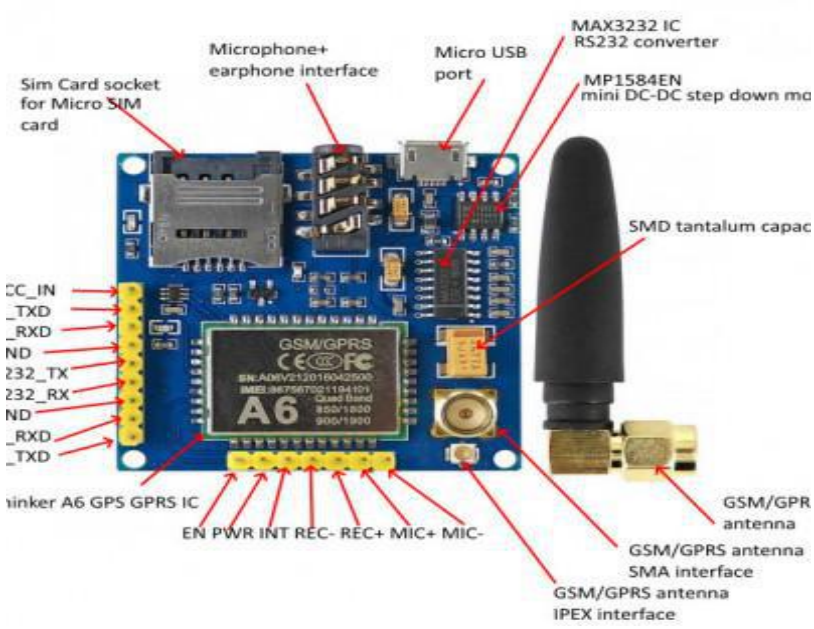


Fig.3.3 GSM Modual

4) GPS Module (NEO-6M): The NEO-6M GPS module is a satellite-based positioning device that provides accurate latitude and longitude coordinates. It operates by receiving signals from multiple Global Positioning System (GPS)

satellites and calculating the device's exact location. The module communicates with microcontrollers like Arduino using the UART (serial communication) protocol. It has a built-in ceramic antenna for better signal reception and supports a baud rate of 9600 bps by default. The GPS module requires an open sky for optimal accuracy, as obstructions like buildings can weaken signals. In this fire safety system, the NEO-6M module retrieves real-time location data and sends it via the GSM module to notify users of the fire incident's location. It operates on 3.3V to 5V power supply and has low power consumption, making it ideal for embedded applications. The module uses NMEA (National Marine Electronics Association) protocol to send location data in the form of standard sentences. The positioning accuracy is around 2.5 meters, which is suitable for emergency alert systems. Its integration ensures that fire alerts include precise geographical coordinates, allowing quick response and mitigation. This GPS module is shown in below fig.4.4. [9]

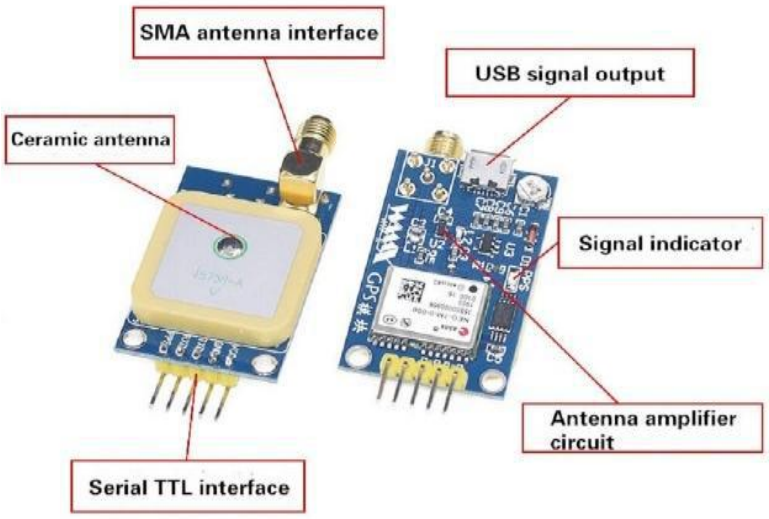


Fig.3.4 GPS Neo-6m

5) Buzzer: A buzzer is an electronic device that produces sound when activated, commonly used for alarms and notifications. It works based on piezoelectric or electromagnetic principles to generate audible alerts. In this fire safety system, the buzzer serves as an immediate warning mechanism by emitting a loud sound when fire is detected. It is connected to the Arduino microcontroller, which triggers the buzzer upon receiving a fire alert signal from the IR sensor. The buzzer operates on a low voltage (typically 3V to 12V) and consumes minimal power. It generates sound by vibrating a diaphragm inside the component when an electrical signal is applied. The frequency of the sound can be controlled using PWM (Pulse Width Modulation) signals from the microcontroller. The buzzer ensures that people nearby are alerted to the fire hazard even before an SMS or call is sent. It is widely used in alarm systems, home automation, and safety devices due to its simplicity and reliability. Its integration into this fire detection system enhances safety by providing an instant audible alert alongside remote notifications. This Buzzer is shown in below fig.4.5.

Fig.3.5 Buzzer

1. System Architecture

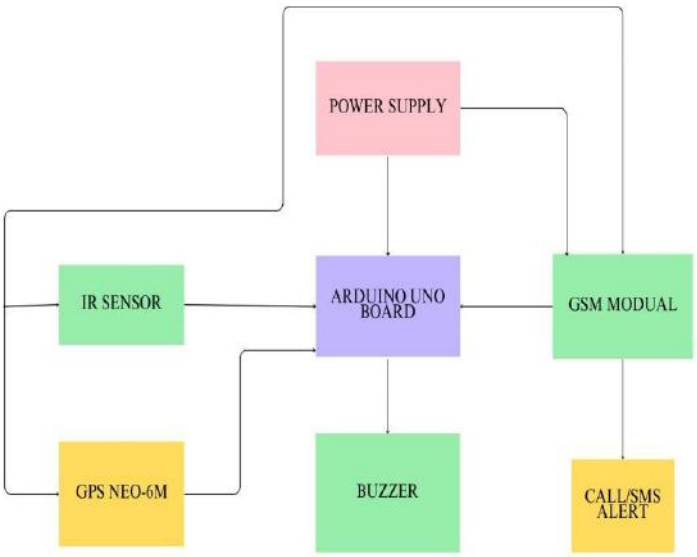


Fig.4.0 Block diagram

The block diagram represents the fire safety system you have developed using Arduino and various hardware components. Below is a detailed explanation of how each module functions and interacts within the system:

1. Power Supply
   - The system is powered by an external power supply, which provides the necessary voltage and current to the Arduino board and all connected components.
2. IR Sensor (Fire Detection Unit)
   - The IR sensor is responsible for detecting fire or high heat sources in the environment.
   - If a fire is detected, the sensor sends a digital signal to the Arduino Uno to trigger the alert mechanism.
3. GPS Module (Neo-6M)
   - The GPS module provides real-time geographical location of the fire incident.
   - Once the IR sensor detects a fire, the Arduino fetches the latitude and longitude coordinates from the GPS module.
4. Arduino Uno (Microcontroller Unit)
   - The Arduino Uno is the central processing unit of the system.
   - It receives inputs from the IR sensor, processes data, and then controls the GSM module and buzzer.
   - It also collects real-time GPS data and formats it into a message for alerts.
5. GSM Module (Communication Unit)
   - The GSM module is used to send an SMS alert or make a call to a predefined phone number when fire is detected.
   - The message contains fire alert information along with the GPS location of the incident.
6. Buzzer (Alarm System)
   - The buzzer is activated when a fire is detected to produce an audible alarm.
   - This serves as a local alert system for nearby individuals to take immediate action.
7. Call/SMS Alert System
   - After receiving the fire detection signal, the GSM module sends a call or SMS alert to notify concerned authorities or users.
   - The message includes location details, helping in quick response and action.

Overall System Working

1. The IR sensor detects a fire and sends a signal to the Arduino.
2. The GPS module retrieves the location of the fire.
3. The Arduino processes the data and activates the buzzer for an alarm.
4. The GSM module sends an SMS/call to alert users about the fire incident.
5. The system continues monitoring for further incidents.

This setup ensures real-time fire detection, location tracking, and immediate alerting, making it an effective fire safety model.

2. System Workflow

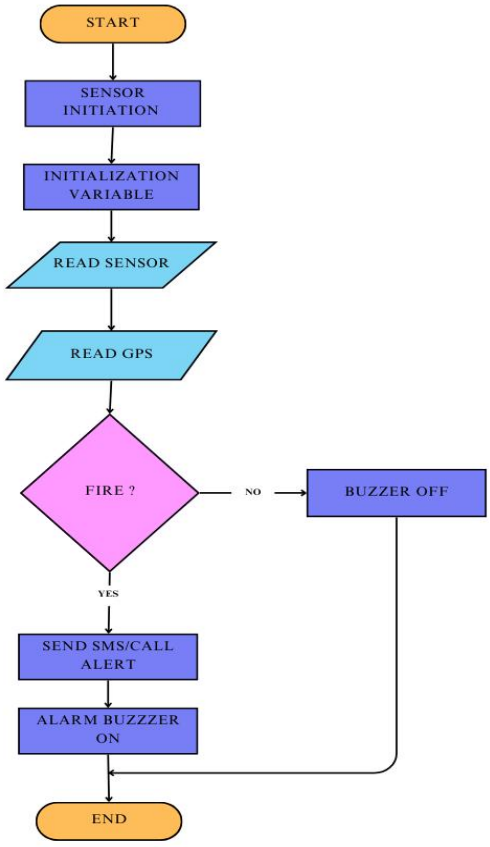


Fig.5.0 Flowchart

This flowchart visually represents the working process of your fire safety system. Below is a step-by-step explanation of the flow:

Step 1: Sensor Initiation
- The system starts by activating the IR sensor and initializing the hardware components, including the GSM module, GPS module, and buzzer.

Step 2: Initialization of Variables
- All necessary variables required for sensor readings, GPS coordinates, and communication are set to default values.

Step 3: Read Sensor Data
- The Arduino continuously reads data from the IR sensor to check for any signs of fire or heat.

Step 4: Read GPS Location
- Simultaneously, the system collects real-time location data from the GPS Neo-6M module.

Step 5: Fire Detection Check
- The system evaluates the sensor readings to determine if fire is detected.
- If fire is detected, the system proceeds to the alert process.
- If no fire is detected, the buzzer remains off, and the system continues monitoring.

Step 6: Alert Process (If Fire Detected)
- The Arduino activates the buzzer to produce a loud alarm.
- The system sends an SMS and/or call alert via the GSM module to predefined emergency contacts.
- The alert message includes the fire alert information and the GPS coordinates to help responders locate the fire.

Step 7: Process Ends
- After sending alerts and sounding the buzzer, the system completes the cycle.
- The system can restart the monitoring process for continuous fire detection.

Looping Mechanism (If No Fire Detected)

- If no fire is detected, the system loops back to continue sensor readings and environmental monitoring, ensuring 24/7 real-time fire detection.

6. Prototype Implementation and Working Model

The prototype of the fire detection and alert system was successfully developed using Arduino as the central controller. Various hardware components such as IR sensor, GPS Neo-6M, GSM module, and buzzer were integrated into a single working model. The system was tested under simulated fire conditions, demonstrating accurate detection and reliable alert generation through SMS and call notifications. The prototype model is show in below fig.8.0.

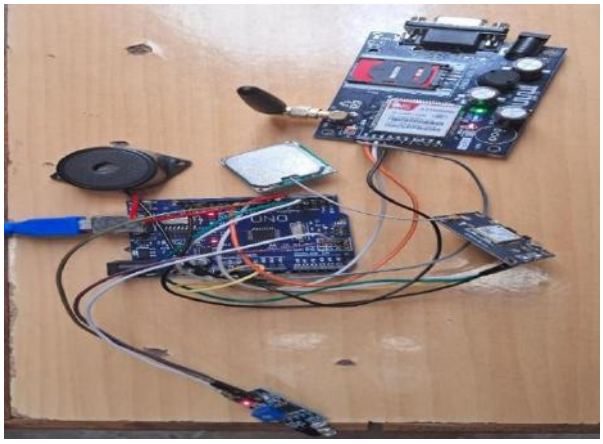


Fig.6.0 Prototype Model

This prototype works by continuously monitoring the presence of fire using an IR sensor. When fire is detected, the Arduino processes the sensor data and immediately triggers the buzzer for a local alarm. Simultaneously, the GPS module retrieves the real-time location coordinates of the system. The GSM module then sends an SMS alert to a predefined contact number, including the detected location. This ensures that both local alerts and remote notifications are provided, enabling quick response in case of fire incidents.

A. Mobile SMS Alert:

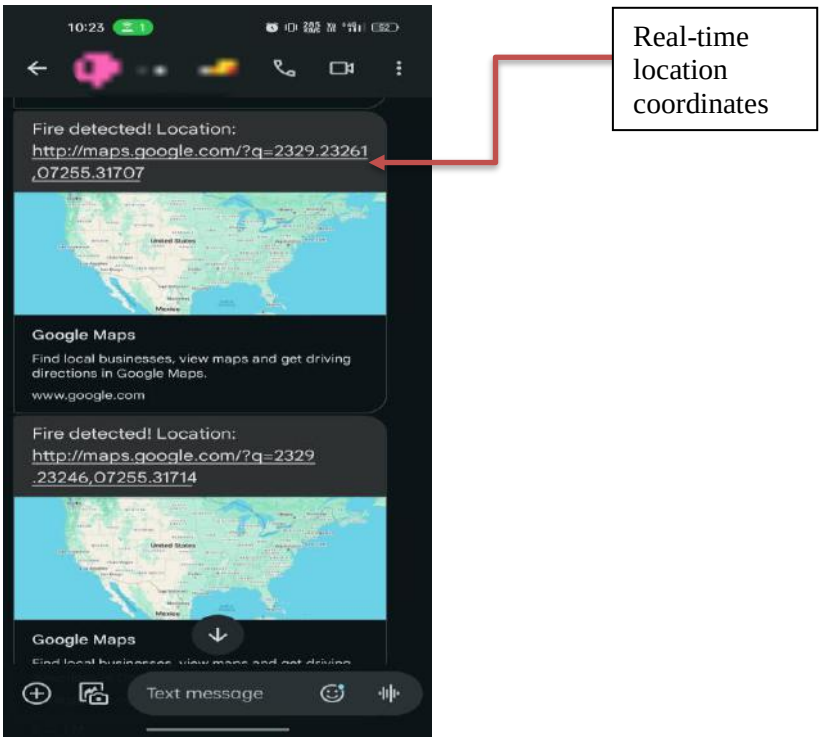


Fig.6.1 Mobile SMS Alert

The above screenshot shows the alert message received on a mobile phone when fire is detected. The message contains the real-time location coordinates fetched using the GPS module, enabling responders to quickly locate the affected area. This instant alert system ensures rapid communication, which is crucial for fire safety and emergency response.

6. CONCLUSION:

The proposed fire detection and alert system is an innovative safety model designed to detect fire incidents and instantly alert responsible authorities through SMS and call notifications. The system integrates multiple hardware components, including an IR sensor, which continuously monitors for fire or flames, and a GPS Neo-6M module to capture the real-time location of the incident. The Arduino UNO serves as the central control unit, processing sensor data and coordinating with communication modules. In case of fire detection, the GSM module (SIM800) sends alert messages containing the GPS coordinates to predefined phone numbers, ensuring quick response. Simultaneously, a buzzer is activated to provide a local alarm for immediate awareness.

The system operates on a power supply connected to the Arduino and other components, ensuring uninterrupted performance. The software implementation involves programming the Arduino to read sensor data, fetch GPS location, and trigger the GSM module when necessary. This prototype offers a low-cost, reliable, and effective solution for fire safety in homes, industries, and remote locations. It bridges sensor technology, wireless communication, and location tracking, making it suitable for various real-world applications. With its modular design, the system can be further upgraded to include smoke sensors, temperature monitoring, or cloud-based data storage for enhanced functionality. Overall, this research paper demonstrates how IoT and embedded systems can significantly improve disaster management and emergency response.

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21. University Journal SPUJSTMR-2024 on *"Smart Irrigation System Using Arduino Board"*