Fire Detection System through IoT-Based

(IoT-Based Real-Time Notification)

A Project Report

Submitted in partial fulfilment of the Requirements for the
award of the Degree of

BACHELOR OF SCIENCE (INFORMATION TECHNOLOGY)

By

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KISHINCHAND CHELLARAM COLLEGE

(Affiliated to HSNC University)

MUMBAI,400020

MAHARASHTRA

2024-25

PROFORMA FOR THE APPROVAL PROJECT PROPOSAL

PNR No: 2022230210020066 Roll No: **KCTYBSC(IT)032**

Name of the Student**: Saumitra Mane**

Title of the Project: **Fire Detection System through IoT-Based**

Name of the Guide: **Mr.Sadiq Batliwala**

Teaching experience of the Guide: 3 Years

Is this your first submission? Yes ☐ No ☐

Signature of the Student Signature of the Guide

Date: ………………… Date: …………………….

Signature of the Co-Ordinator

Date: …………………

KISHINCHAND CHELLARAM COLLEGE

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DEPARTMENT OF INFORMATION TECHNOLOGY

विद्यया विन्दते अमृतम्!

CERTIFICATE

This is to certify that the project entitled, **" Fire Detection System through IoT-Based"**, is bonafied work for IoT efficiency with bearing real time notification with team partner with **Aarti Patel roll no KCTYBSC(IT)038** and **Saumitra Mane roll no KCTYBSC(IT)032** submitted in partial fulfilment of the requirements for the award of degree of BACHELOR OF SCIENCE in INFORMATION TECHNOLOGY from HSNCU University.

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External Examiner

Date: **College Seal**

ACKNOWLEDGEMENT

We would like to take this opportunity to express a deep sense of gratitude to Dr. Tejashree V. Shanbhag (Principal of K.C. College) and Dr. Rakhi Gupta (H.O.D. of B.Sc. I.T. Department) for their cordial support, valuable information and guidance, which helped us in completing this task through various stages. We take this opportunity to express ourprofound gratitude and deep regards to our guide, Mr. Sadiq Batliwala for his exemplary guidance, monitoring and constant encouragement throughout the course of this project. The blessing, help and guidance given by her time-to-time shall care us a long way in the journey of life onwhich we are about to embark.

We are obliged to staff members of K.C. College for the valuable information provided by them in their respective fields. We are grateful for their cooperation during the period of our project.

-Saumitra Mane

DECLARATION

I hereby declare that the project entitled, **“Fire Detection System through IoT-Based** done at **K.C. College** is done, has not been in any case duplicated to submit to any other university for the award of any degree. To the best of my knowledge other than me, no one has submitted to anyother university.

The project is done in partial fulfillment of the requirements for the award of degree of **BACHELOR OF SCIENCE (INFORMATION TECHNOLOGY)** to be submitted as final semester project as part of our curriculum.

Name and Signature of the Student

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ABSTRACT

The efficiency of Fire Detection operations is often hindered by delayed detection, inefficient resource allocation, and communication breakdowns during emergencies. Traditional fire detection systems are typically inadequate in providing early warnings, thereby increasing the risks for both firefighters and building occupants. This project aims to enhance Fire Detection efficiency through the integration of Internet of Things (IoT) technology into existing systems. By deploying IoT-enabled sensors, microcontroller and communication module we propose a robust real -time notification system that significantly improves monitoring, automated alerts, and communication. The methodology involves the design and implementation of a comprehensive IoT-based Fire Detection system incorporating various sensors for real-time detection of heat and fire establishing a reliable communication network, and implementing an automated alert system. This approach is expected to enhance the safety and efficiency of Fire Detection operations, ultimately reducing casualty rates and property damage.The integration of mobile devices for real-time notifications further ensures that all stakeholders are promptly informed, enabling swift and coordinated emergency responses.

Keywords: Fire Detection Efficiency, IoT, Real-Time Notification System, Automated Alerts, Sensor Deployment, Communication Network, Data Analytics, Emergency Response, Safety.

CHAPTER 1

Chapter- 1
INTRODUCTION

1.1 BACKGROUND

- Fire Detection is a critical service for ensuring public safety and protecting property. Fires pose a constant threat to life and property.
- Traditional Fire Detection methods rely on human response and may be hindered by delayed detection, limited situational awareness, and the inherent dangers firefighters face. The integration of Internet of Things (IoT) technologies offers innovative solutions to enhance Fire Detection efficiency, enabling faster response times, improved situational awareness, and optimized resource management.
- IoT-enabled sensors can provide real-time data on various parameters such as temperature, smoke density, and gas levels. This data can be analyzed by AI algorithms to identify potential fire hazards, predict fire spread, and optimize Fire Detection strategies.
- IoT sensors can be used to monitor the condition of Fire Detection equipment, allowing for predictive maintenance to be scheduled. This helps prevent equipment failures and ensures that Fire Detection tools are always in optimal working condition.

1.2 OBJECTIVES

The primary objectives of Fire Detection efficiency are:

1. **Early Fire Detection and Response:** Develop an IoT-based Fire Detection system that utilizes a network of interconnected sensors to detect fires at the earliest stages. This will enable rapid response times and minimize property damage.

2. **Real-time Situational Awareness:** Leverage IoT data to provide firefighters with real-time information on fire location, spread, and potential hazards. This will enhance situational awareness and support informed decision-making.

3. **Enhanced Emergency Response Coordination:** Integrate IoT solutions with existing emergency response systems to improve communication, coordination, and resource allocation. This will streamline the Fire Detection process and ensure effective collaboration among different agencies.

4. **Optimized Resource Management:** Use IoT data to optimize the deployment of Fire Detection resources, ensuring that personnel and equipment are allocated efficiently based on the severity and location of the fire.

5. **Improved Firefighter Safety:** Implement IoT-enabled safety features, such as real-time loc tracking, to enhance firefighter safety and reduce the risk of injuries.

1.3 PURPOSE, SCOPE, APPLICABILITY

1.3.1 PURPOSE

The project aims to enhance Fire Detection efficiency through the integration of IoT-based solutions. By leveraging advanced technologies such as smart sensors, wireless sensor networks, , the project seeks to address the limitations of traditional Fire Detection methods. This involves developing systems for real-time fire detection, improved communication, optimized resource management, and enhanced safety measures for firefighters.

1.3.2 SCOPE

The scope of this project encompasses the development of an IoT-based fire response system designed to deploy a network of sensors including, heat and fire detectors for early fire detection. It focuses on establishing a robust communication infrastructure to acquire real-time sensor data and analyze it promptly. The system aims to provide people with accurate information on fire location, intensity, and environmental conditions.

1.3.3 APPLICABILITY

The applicability of this project extends across multiple domains, benefiting Fire Detection operations, computer science advancement, and public safety. By implementing IoT-based systems, it enhances real-time monitoring and alert capabilities, enabling swift detection of fire hazards and timely alerts to minimize damage.

1.4 ACHIEVEMENTS

A. Real-Time Fire Detection & Alerts

- Detects fire using flame sensors and heat sensors.
- Sends instant SMS alerts to emergency contacts (fire department, homeowners, etc.).
- Calls predefined numbers in case of fire for urgent alerts.
- Activates a buzzer to warn nearby people.

B. Remote Monitoring & Control

- Works without the internet (using GSM for SMS/calls).
- Can be placed in remote areas like forests, warehouses, and factories.
- Users can send an SMS command to check sensor status.
- Can be integrated with ESP32-CAM for live fire detection images/videos.

C. Enhanced Safety & Security

- Helps in early fire detection, preventing major damage.
- Reduces the need for human supervision in fire-prone areas.
- Can be linked to an automatic fire suppression system (sprinklers, CO2 extinguishers).

D. Cost-Effective & Scalable Solution

- Low-cost alternative to expensive commercial fire alarm systems.
- Can be installed in homes, industries, schools, and public places.
- Easily scalable – more sensors and modules can be added.

E. Energy-Efficient & Reliable

- Works on battery backup, making it functional during power outages.
- Consumes low power, ensuring long-term operation.
- Can operate in harsh environments with proper casing.

1.5 ORGANISATION OF REPORT

- **In chapter 1-Introduction** The project focuses on enhancing Fire Detection efficiency through an IoT-based system that uses interconnected sensors for early fire detection and real-time data analysis. The objective is to improve situational awareness, optimize resource management, and integrate predictive analytics with emergency response systems. The project aims to overcome the limitations of traditional Fire Detection methods by leveraging advanced technologies such as smart sensors, wireless networks, and AI.
- In **chapter 2-Survey of Technologies** will summarize the details of the technologies that are necessary to complete the project.
- In **chapter 3- Requirement Analysis** problem statement will be defined which will be divided into sub problems. Requirement specifications will describe the things in the system and the actions that can be done on these things. In the planning and scheduling Gantt chart and PERT will be made, also the hardware and software specification will be defined.Conceptual Models will also be made.
- **Chapter 4- System Design** describes desired features and operations in detail including screen layout, business rules, process diagrams and other documentation.
    - Basic Modules: The students should follow the divide and conquer theory, so divide the overall problem into more manageable parts and develop each part or module separately.
    - Data Design: Data design will consist of how data is organized, managed, and manipulated.
- **Chapter 5- Implementation and Testing** Each component (sensor module, alert system) is developed and integrated separately. IoT sensors are programmed to detect temperature, smoke, and heat levels. Testing includes unit, integration, and system testing to verify functionality. Test cases confirm accurate detection and alert mechanisms.
- **Chapter 6: Results and Discussion** Test reports indicate the system's high accuracy in detecting fire events. User documentation provides installation steps, system configuration, and alert management. The workflow explains data flow from sensors to cloud and alert triggers. Screenshots showcase real-time monitoring, hardware setup, and system alerts.
- **Chapter 7: Conclusion** The IoT-based fire detection system enhances early fire detection through smart sensors and real-time monitoring. Despite challenges like false alarms and network dependency, the system improves response time. Limitations include hardware durability and occasional false triggers. Future enhancements include AI-based prediction, drone integration, and wider industrial applications.

- **Chapter 8: Cost Estimation:** The IoT-based fire detection system is a cost-effective solution that enhances fire safety through real-time alerts. The overall cost includes hardware, software, and deployment, with long-term savings outweighing initial investments. Testing and maintenance expenses are minimal, ensuring system reliability and efficiency. The benefits include improved safety, scalability, and integration with advanced technologies like AI for predictive fire detection.
- The IoT-based fire detection system improves fire safety by providing real-time alerts and rapid response. It is a cost-effective and scalable solution with minimal maintenance requirements. Challenges like network dependency and false alarms can be addressed with AI integration. Future enhancements include predictive analytics and drone-based monitoring for better fire prevention.

CHAPTER 2

Chapter- 2
SURVEY OF TECHNOLOGIES

2.1 FRONT-END

FEATURES

We'll develop a reliable fire detection system using Arduino Uno, GSM module, ESP32-CAM, flame sensor, and heat sensor. The system will provide real-time fire alerts via SMS and calls using the GSM module, while the ESP32-CAM can capture live images for remote monitoring. Additionally, we will implement automatic fire detection and response mechanisms, including a buzzer alarm and potential integration with fire suppression systems. The system will be designed for low power consumption and can operate on a battery backup to ensure functionality during power outages.

Incident Details:

- **Purpose:** Provide detailed information about each fire incident, including location, time, sensor readings, severity, and response status.
- **Usage:** Display relevant information in **a** clear and concise format**,** using SMS alerts or a web dashboard for real-time monitoring.

Fire Detection Monitoring:

- **Purpose:** Continuously monitor fire-prone areas using flame sensors, heat sensors, and ESP32-CAM for real-time image capture.
- **Usage:** Use an IoT-based dashboard to display live sensor data and images from fire detection sites.

Resource Allocation Dashboard:

- **Purpose:** Visualize the availability and utilization of fire detection resources, including deployed sensors, active GSM alerts, and system health.
- **Usage:** Use charts and logs to display fire alert history, sensor performance, and response times.

Emergency Alerts and Notifications:

- **Purpose:** Send timely alerts and notifications to relevant personnel, including firefighters, emergency responders, and property owners**.**

- **Usage:** Utilize SMS, call notifications, and email alerts through the GSM module for immediate response.

Integration with Fire Detection Equipment:

- Purpose**:** Provide real-time status updates on fire detection equipment, ensuring system reliability.
- Usage: Integrate with IoT sensors to monitor temperature, flame presence, and system battery level**.**

2.2 HARDWARE FEATURES

List of components required

- Flame Sensor
- Temperature Sensor (MAX6675 + K Type Thermocouple)
- 5V Active Buzzer
- Arduino Uno
- ESP32-CAM (Camera Module)
- GSM Module (For Alerts)
- Breadboard
- Jumper Wires (Pack)
- ESP32-CAM-MB Micro USB

1. Flame Sensor

- Detects the presence of fire or flame by sensing infrared (IR) light emitted from flames.
- Sends a digital or analog signal to the **Arduino Uno** for fire detection.

2. Temperature Sensor (MAX6675 + K Type Thermocouple)

- Measures high-temperature levels accurately.
- Converts temperature readings into digital data for the **Arduino U**

3. 5V Active Buzzer

- Produces an audible alarm when fire or excessive heat is detected.
- Activated by the **Arduino Uno** when fire conditions are met.

4. Arduino Uno

- Acts as the main **microcontroller**, processing data from sensors.
- Controls the **buzzer**, **GSM module**, and **ESP32-CAM** for real-time alerts.

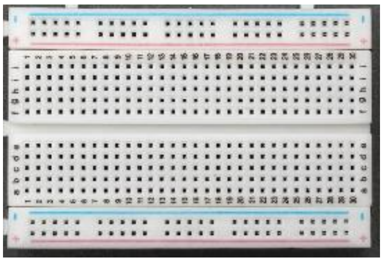
5. ESP32-CAM (Camera Module)

- Captures real-time images or video streams of the fire detection site.
- Can be accessed remotely via a web interface or an SMS link.

6. GSM Module (For Alerts)

- Sends **SMS and calls** to notify users about fire detection.
- Communicates with the **Arduino Uno** for real-time alert transmission.

7. Breadboard



- Provides a **temporary circuit setup** for connecting components without soldering.
- Allows easy modifications during testing and prototyping.

8. Jumper Wires (Pack)

- Used to connect components on the breadboard.
- Enables data and power transmission between the **Arduino, sensors, and modules**.

9. ESP32-CAM-MB Micro USB

- A programmer board for the **ESP32-CAM**, allowing easy code uploading and power supply.
- Helps in debugging and configuring the camera module.

10. 12V 3Ah Li-ion Lithium Rechargeable Battery

- Provides **backup power** to keep the fire detection system running during a power outage.
- Ensures continuous operation of **Arduino, ESP32-CAM, GSM module, and sensors**.

CHAPTER 3

Chapter- 3
REQUIREMENTS AND ANALYSIS

3.1 PROBLEM DEFINITION

The traditional Fire Detection methods are often reactive, responding to emergencies after they occur, which can lead to delays and increased damage. The lack of real-time data, communication gaps, and inefficient resource allocation often hinder the effectiveness of Fire Detection operations. To enhance Fire Detection efficiency, there is a need for an advanced system that integrates real-time monitoring, data analysis, and automated responses using IoT technology.

- Inefficient resource allocation: Misallocation of Fire Detection resources due to lack of real-time information.
- Safety risks: Exposure of firefighters to hazardous environments due to limited visibility and situational awareness.
- Property damage: Extensive damage to property and infrastructure due to uncontrolled fire spread.

3.2 REQUIREMENT SPECIFICATION

a) The system's functional requirements include real-time monitoring capabilities to continuously track environmental parameters such as temperature, and fire , ensuring immediate detection of any abnormalities.

b) Upon detecting unusual conditions, the system should promptly send alerts to Fire Detection units and authorities to enable swift action.

c) Additionally, the system must integrate with Fire Detection equipment to trigger automated responses, such as activating sprinkler systems or fire extinguishers, to control or suppress fires before they escalate.

d) All data collected should be logged for future analysis and reporting, aiding in post-incident evaluations and system improvements. Finally, the system should feature a user-friendly interface that allows users to monitor and control the system.

3.3 SOFTWARE AND HARDWARE REQUIREMENTS

- **Software Requirements**:
  - Operating System: Windows
  - Programming Languages: C/C++
  - Development Tools: Arduino IDE
  - Communication Protocols: SMS, phone calls
- **Hardware Requirements**:
  - Sensors: Flame sensors, smoke detectors, temperature sensors.
  - Microcontroller: Arduino UNO.
  - Communication Module: GSM Module.
  - Actuators: Active Buzzer.
  - Power Supply: Batteries, power adapters.
  - Additional Components: Jumper wires, Breadboard, 12V 3Ah Li-ion Lithium Rechargeable Battery

3.4 Planning and Scheduling

Phase 1: Research and Analysis: Understand the current Fire Detection methods and identify key areas for improvement using IoT.

Phase 2: System Design: Design the architecture, including hardware and software components.

Phase 3: Development: Implement the system’s software, hardware integration, and network setup.

Phase 4: Implementation and Testing: Making the project implement sensors, testing real-time alerts, and validating network reliability.

Phase 5: Results and Discussion: Analyzing test outcomes, optimizing system performance, and improving accuracy.

3.4 Planning and Scheduling

Task	Start Date	End Date	Duration
Selection and Approval	1-07-2024	5-07-2024	5
Feasibility Study	05-07-2024	12-08-2024	27
Requirement specification	12-08-2024	15-08-2024	4
Analysis	15-08-2024	26-08-2024	8
Design	26-08-2024	01-10-2024	27
Implementation and Testing	29-11-2024	17-02-2025	100
Results and Discussion	17-02-2025	10-03-2025	16
Cost Estimation	10-03-2025	14-03-2025	5
Report Making	01-07-2024	14-03-2025	185

- **Gantt Chart**:

A Gantt chart can be developed to visualize the timeline of each phase and task.

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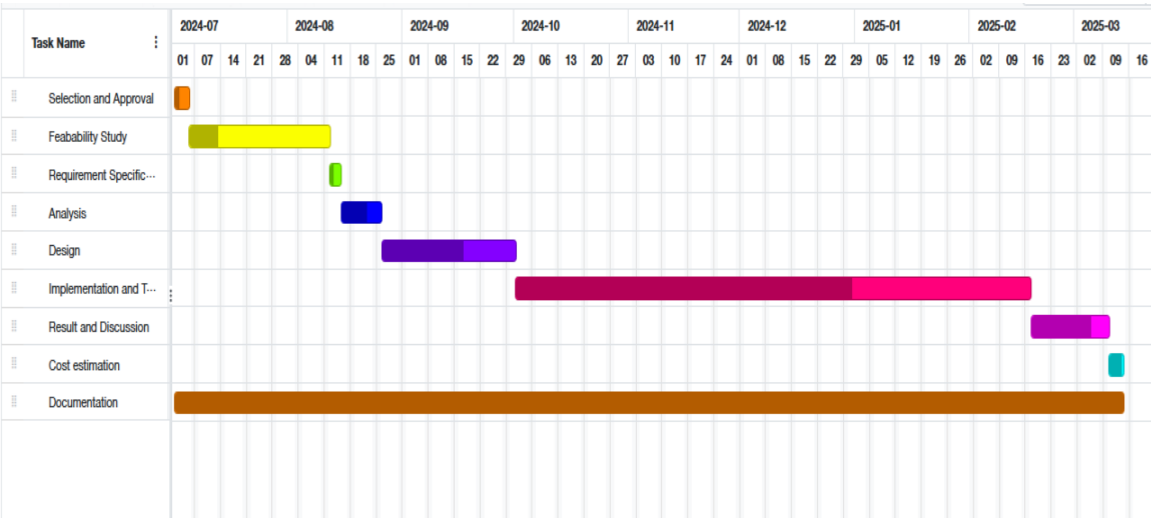


Figure 3.1:Gantt chart

CHAPTER 4

Chapter- 4
SYSTEM DESIGN

System design refers to the process of defining the architecture, components, modules, interfaces, and data for a system to satisfy specified requirements. It outlines how the various parts of a system will work together to achieve the project's goals, addressing both functional and non-functional requirements.

Importance of System Design:

1. **Blueprint for Development**: It serves as a foundation for developers to follow, ensuring consistency and efficiency during development.
2. **Problem Identification**: By designing the system upfront, potential issues can be identified early, reducing the chances of costly fixes later on.
3. **Scalability**: A well-designed system can easily scale to accommodate growth in user base, data, and functionality.
4. **Maintainability**: Good system design ensures that the system is easier to maintain, with modular and well-documented components.
5. **Efficiency**: Helps in optimizing resource usage (memory, processing power) to achieve better performance.
6. **Security and Reliability**: Ensures that proper security measures are in place to protect the system and that it performs reliably under expected conditions.

4.1) DATA FLOW DIAGRAMS.

A Data Flow Diagram (DFD) is a graphical representation that depicts the flow of data within a system, showing how inputs are processed into outputs. It is used in system design to visualize how data moves between processes, entities, and data stores, making it easier to understand how the system functions.

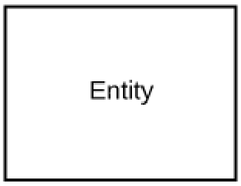
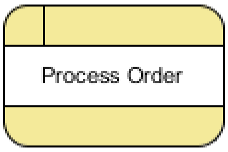
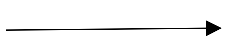
Symbol	Name	Description
	**External entity**	External entities are objects outside the system with which system communicates. These are sources and destinations of the system inputs and outputs.
	**Process**	A process receives input data and process output data with a different form or content. Every process has a name that identifies the function it performs.
	**Data flow**	Data flow is the path for data to move from one part of the system to another. It may be a single data element or set of data element. The symbol of data flow is the arrow. The arrow shows the flow direction.
	**Data Store**	It is used to store information that the system needs to retain and can be accessed by different processes for reading or writing data. Data stores help in managing persistent data that isn't directly provided by external entities but is crucial for system operations

Table-4.1 Data Flow diagram

4.1.1) DFD Level 0.

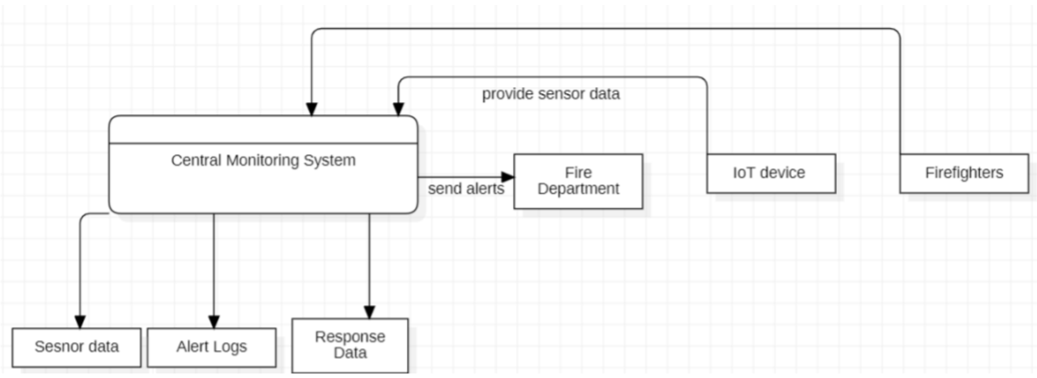


Figure 4.1.1-DFD LEVEL 0

Components for Level 0 DFD on "Fire Detection System through IoT-Based Systems":

1. External Entity - Firefighters:

A rectangle on the left.

This entity represents the firefighters who interact with the IoT-based Fire Detection system to receive alerts and instructions.

2. External Entity - IoT Devices:

A rectangle on the left.

This entity includes sensors, alarms, and cameras that monitor the environment and detect fire-related risks.

3. External Entity - Fire Department:

A rectangle on the left.

This entity represents the fire department that receives alerts from the system and coordinates the deployment of Fire Detection resources.

4. Process - Central Monitoring System:

A rounded rectangle in the middle.

This process is the core of the IoT-based system, where data from IoT devices is analysed, and appropriate actions such as sending alerts and managing resources are performed.

4.1.2) DFD Level 1.

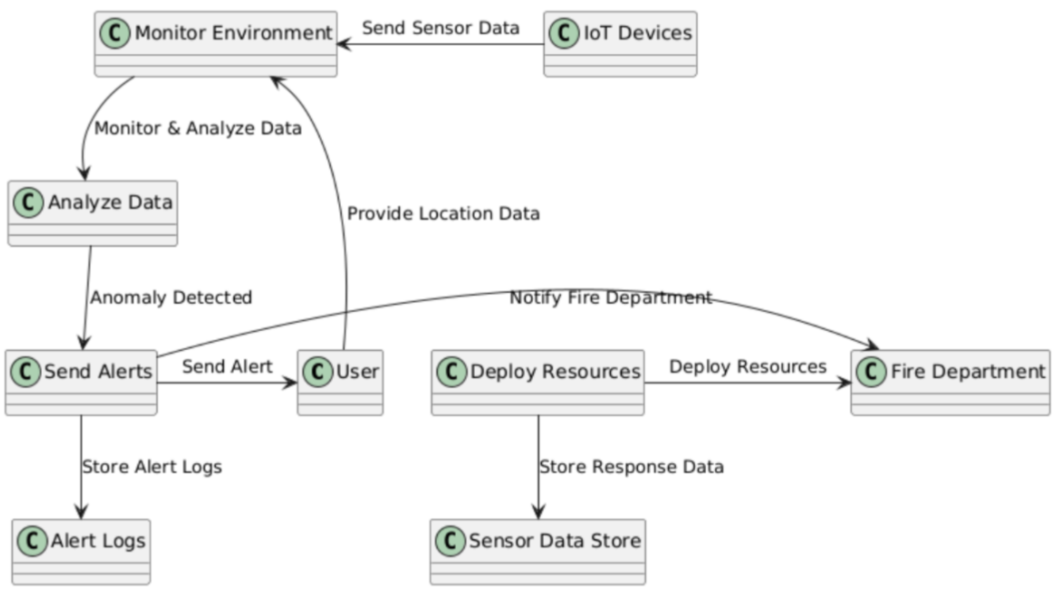


Figure 4.1.2 DFD LEVEL 1

Components:

1. **External Entity - Firefighter/User:**

Represents the person interacting with the Fire Detection system (firefighters or emergency responders).

2. **Processes**:

- **User Registration and Login:** Manages the authentication, registration, and login procedures for firefighters or users.
- **Monitor Environment:** Continuously monitors the environment through IoT devices like sensors to detect fire-related anomalies.
- **Analyse Data:** Analyses the data collected from the IoT devices to identify any potential fire threats or unusual activity.
- **Send Alerts:** Sends alerts to firefighters and the fire department when a potential fire is detected.
- **Deploy Resources:** Manages the deployment of Fire Detection resources based on the severity of the detected fire.
- **Manage User Profile:** Handles the user profile management, allowing firefighters to set preferences and update personal information.
- **System:** Acts as the central processing unit that handles user input, verifies data, processes requests, and coordinates the entire Fire Detection operation.

3. **Data Stores**:

- Sensor Data: Stores real-time readings from flame sensors, heat sensors, and ESP32-CAM to monitor fire-prone areas.
- Alert Logs: Maintains records of all fire alerts sent via SMS and calls, including timestamps, sensor readings, and detected fire severity.
- Response Data: Stores information on fire incident responses, including alert acknowledgment, response times, and actions taken (e.g., buzzer activation, fire suppression deployment)..

Relationships:

- Firefighter/User submits data and interacts with various processes, starting with registration and login.
- Monitor Environment continuously receives data from IoT devices (e.g., temperature sensors, smoke detectors) and passes this information to Analyse Data for processing.
- Analyse Data checks the incoming data for signs of fire, passing any significant

findings to Send Alerts.

- Send Alerts then notifies both the Firefighter/User and the Fire Department of the detected fire threat.
- Deploy Resources decides on the appropriate Fire Detection resources to dispatch based on the severity of the alert and stores this information in Response Data.

4.2) FLOW CHART DIAGRAM.

A flowchart is a graphical representation of a process, system, or algorithm that uses various symbols to denote different steps and arrows to show the flow of execution. It is used to visualize and communicate how a process works, showing the sequence of steps and the decisions that need to be made along the way.

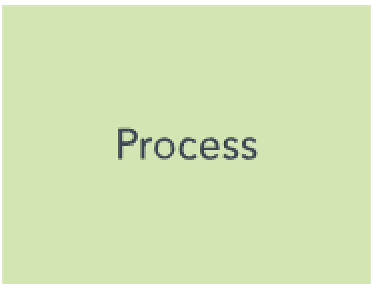
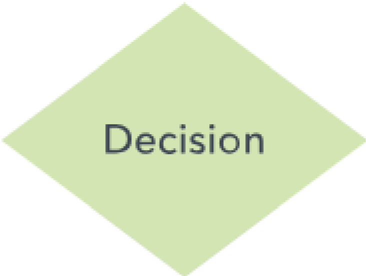
Symbol	Name	Description
	Rectangle (Process)	Represents a process, action, or operation. Typically contains a brief description of the step.
	Process	Represents a decision point where a choice is made. Often contains a question or condition. Typically has multiple outgoing arrows representing different possible outcomes based on the decision.
	Arrow	Indicates the direction of flow between steps. Connects different symbols in the flowchart.

Table 4.2 FLOW CHART

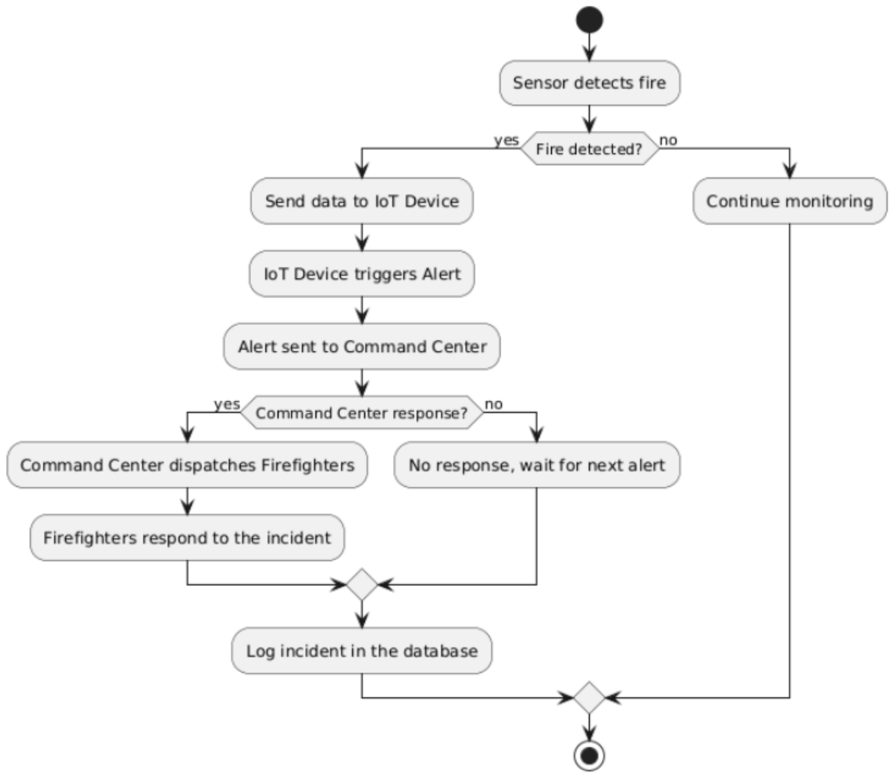


Figure 4.2 FLOW CHART

Components:

- IoT Sensors: Detect fire through various means (e.g., heat, smoke, flame detection).
- IoT Gateway: Collects sensor data and transmits it to the cloud.
- Cloud Platform: Processes data, analyses for fire threats, and triggers alerts.
- Alert System: Notifies relevant authorities (e.g., fire department, building management).
- Fire Detection Personnel: Respond to alerts and extinguish fires.
- Database: Records incident details for analysis and improvement.

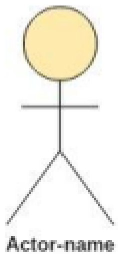
Relationships:

- Detection: IoT sensors detect fire and send data to the IoT gateway.
- Data Transmission: The IoT gateway transmits sensor data to the cloud platform.
- Analysis: The cloud platform analyses data to determine if a fire has occurred.
- Alerting: If a fire is detected, the cloud platform triggers alerts to Fire Detection personnel and relevant authorities.
- Response: Fire Detection personnel respond to the incident based on the alert information.
- Recording: Incident details are logged in the database for future analysis.

4.3) USE CASE DIAGRAM.

A **use case diagram** is a type of behavioral diagram defined by the Unified Modeling Language (UML) that represents the interactions between users (actors) and a system. It is used to capture the functional requirements of a system, showing how different types of users interact with various use cases (functionalities or services) provided by the system.

Table 4.3 Use case

Symbol	**Name**	**Description**
	User	Use cases are used to represent high-level functionalities and how the user will handle the system. A use case represents a distinct functionality of a system, a component, a package, or a class. It is denoted by an oval shape with the name of a use case written inside the oval shape
	Use Case	Use cases are used to represent high-level functionalities and how the user will handle the system. A use case represents a distinct functionality of a system, a component, a package, or a class. It is denoted by an oval shape with the name of a use case written inside the oval shape

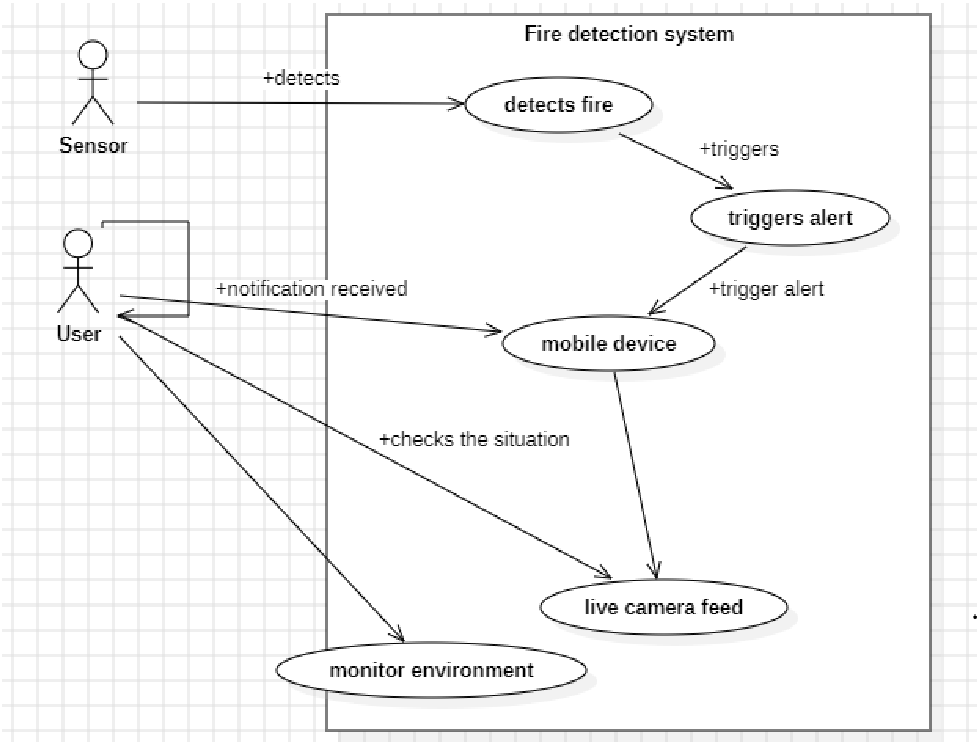


Figure 4.3 Use Case

Actors:

- Firefighter: Represents the personnel responsible for extinguishing fires.
- Command Center: Represents the central authority responsible for coordinating Fire Detection operations.
- Sensor: Represents the device used to detect fires.
- IoT Device: Represents the device that communicates with the sensor and transmits data.

System Boundary:

- The rectangle labeled "Fire Detection System" defines the boundaries of the system, encompassing all the entities and their interactions.

Use Cases:

- Detect Fire: The sensor detects the presence of a fire.
- Monitor Environment: The IoT device continuously monitors the environment for signs of a fire.
- Trigger Alert: The IoT device triggers an alert when a fire is detected.
- Dispatch Firefighters: The command center receives the alert and dispatches firefighters to the scene.
- Combat Fire: The firefighters extinguish the fire.
- Log Incident: The command center logs details of the incident for future reference.

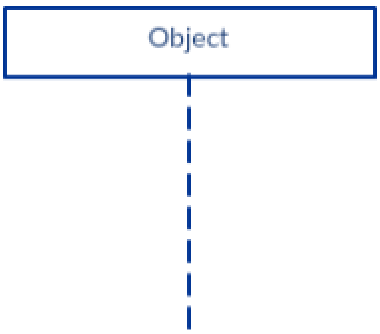
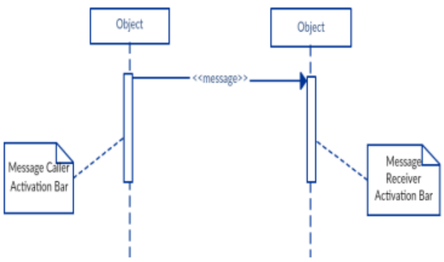
Relationships:

- Association: The lines connecting the actors and use cases represent associations, indicating that they interact with each other.
- Dependency: The arrow from "Sensor" to "Trigger Alert" indicates a dependency, meaning the sensor is required to trigger the alert.
- Sequence: The arrows between the use cases suggest a sequence of actions, starting with "Detect Fire" and ending with "Log Incident."

4.4) SEQUENCE DIAGRAM.

A sequence diagram is a type of interaction diagram that shows the flow of messages between objects in a system over time. It's often used to model the behavior of a system, analyze its interactions, and identify potential issues or bottlenecks.

Table 4.4 Sequence

Symbol	Name	Description
	Lifeline Notation	A sequence diagram is made up of several of these lifeline notations that should be arranged horizontally across the top of the diagram. No two lifeline notations should overlap each other.
	Activation Bars	Activation bar is the box placed on the lifeline. It is used to indicate that an object is active (or instantiated) during an interaction between two objects. The length of the rectangle indicates the duration of the objects staying active.
	Synchronous Message	A synchronous message is used when the sender waits for the receiver to process the message and return before carrying on with another message.

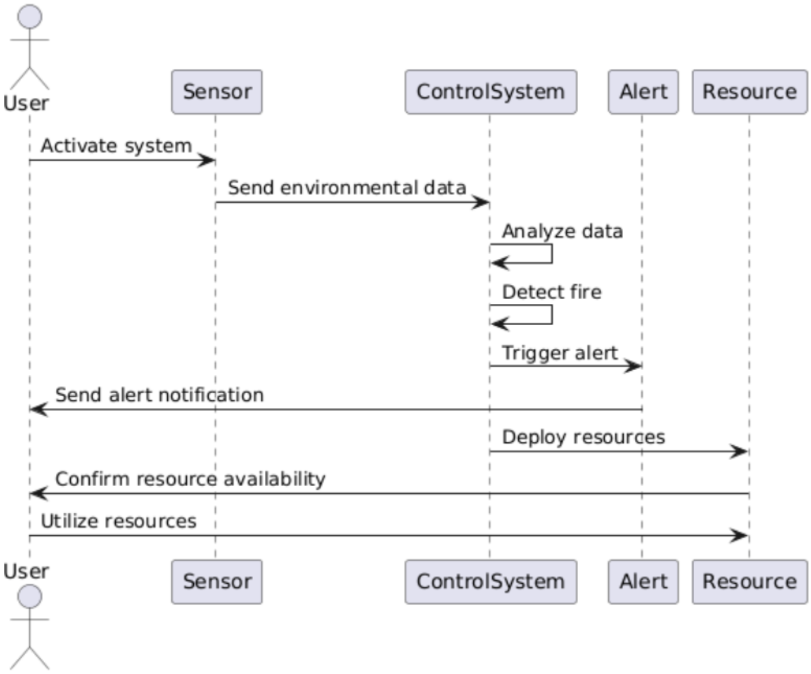


Figure 4.4 Sequence diagram

Lifelines:

- User (Firefighter): Represents the firefighter or end-user interacting with the IoT-based system.
- Sensor Module: Detects fire through sensors like smoke detectors, temperature sensors, etc.
- Data Validation Module: Validates the data received from the sensors to ensure accuracy.
- Alert System: Triggers alerts to notify the firefighter and other relevant authorities.
- Control System: Represents the main control system that coordinates the fire detection system.
- Resource Deployment Module: Manages the deployment of resources like water sprinklers, fire extinguishers, etc.

- Monitoring Dashboard: Displays real-time data and system status to the firefighter.

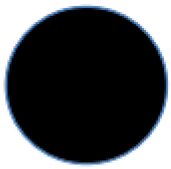
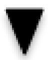
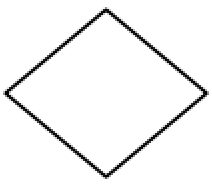
Messages:

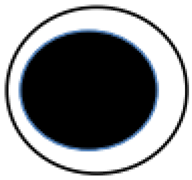
- Activate System: The firefighter activates the Fire Detection system.
- Data Collection: The Sensor Module collects data on environmental conditions.
- Validate Sensor Data: The Data Validation Module validates the data received from the sensors.
- Validation Result: The validation result is returned to the Control System.
- Analyze Data: The Control System analyzes the validated data to detect any fire hazards.
- Fire Detected: If fire is detected, the Control System sends a detection message.
- Trigger Alert: The Alert System triggers an alert to notify the firefighter and other authorities.
- Notify Firefighter: The Alert System sends a notification to the firefighter.
- Deploy Resources: The Resource Deployment Module is activated to deploy resources like water sprinklers or fire extinguishers.
- Control System Commands: The Control System sends commands to the deployed resources.
- Resource Status: The Resource Deployment Module sends the status of the resources back to the Control System.
- Update Dashboard: The Monitoring Dashboard updates with real-time data and status.
- Review Status: The firefighter reviews the status on the Monitoring Dashboard and takes necessary actions.

4.5) ACTIVITY DIAGRAM.

An activity diagram is a type of behavioral diagram that shows the flow of activities in a system. It's often used to model business processes, workflows, and the logic behind a system's operations.

Table 4.5 Activity

Symbol	**Name**	**Description**
	Start symbol	Represents the beginning of a process or workflow in an activity diagram. It can be used by itself or with a note symbol that explains the starting point.
	Activity Symbol	Indicates the activities that make up a modeled process. These symbols, which include short descriptions within the shape, are the main building blocks of an activity diagram.
	Connector Symbol	It shows the directional flow, or control flow, of the activity. An incoming arrow starts a step of an activity; once the step is completed, the flow continues with the outgoing arrow.
	Decision Symbol	Represents a decision and always has at least two paths branching out with condition text to allow users to view options. It represents the branching or merging of various flows with the symbol acting as a frame or container.

	End Symbol	Marks the end state of an activity and represents the completion of all flows of a process.

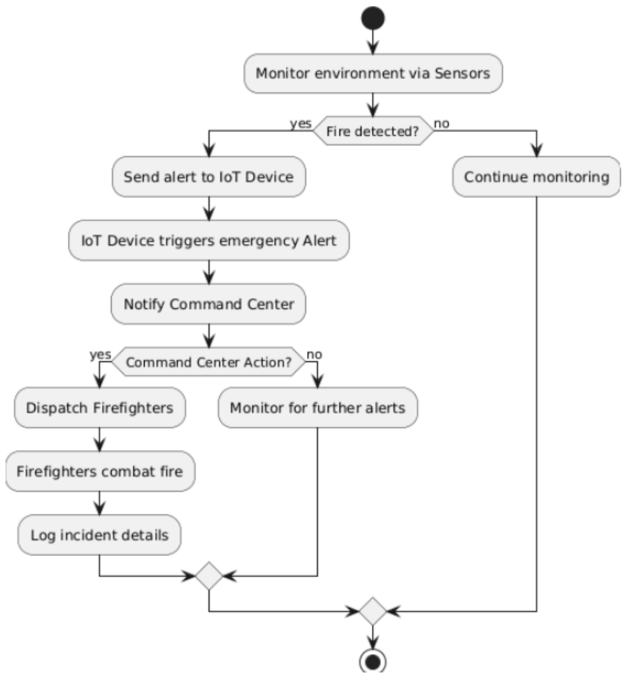


Figure 4.5 Activity Diagram

Activities:

- Monitor Environment via Sensors: The system continuously monitors the environment using sensors to detect potential fire hazards.
- Send Alert to IoT Device: If a fire is detected, an alert is sent to the IoT device.
- IoT Device Triggers Emergency Alert: The IoT device processes the alert and triggers an emergency alert.
- Notify Command Center: The emergency alert is sent to the command center.
- Command Center Action: The command center decides on the appropriate course of action based on the
- Alert
- Dispatch Firefighters: If necessary, the command center dispatches

firefighters to the scene.

- Firefighters Combat Fire: The firefighters work to extinguish the fire.

Relationships:

- Start Node: The process begins with monitoring the environment.
- Decision Node: The system checks if a fire has been detected.
- Fork Node: If a fire is detected, the process branches into notifying the command centre and continuing to monitor the environment.
- Join Node: The processes of notifying the command centre and monitoring the environment converge.
- Decision Node: The command centre decides whether to dispatch firefighters.
- Fork Node: If firefighters are dispatched, the process branches into combatting the fire and logging incident details.
- End Node: The process ends after the incident is logged.

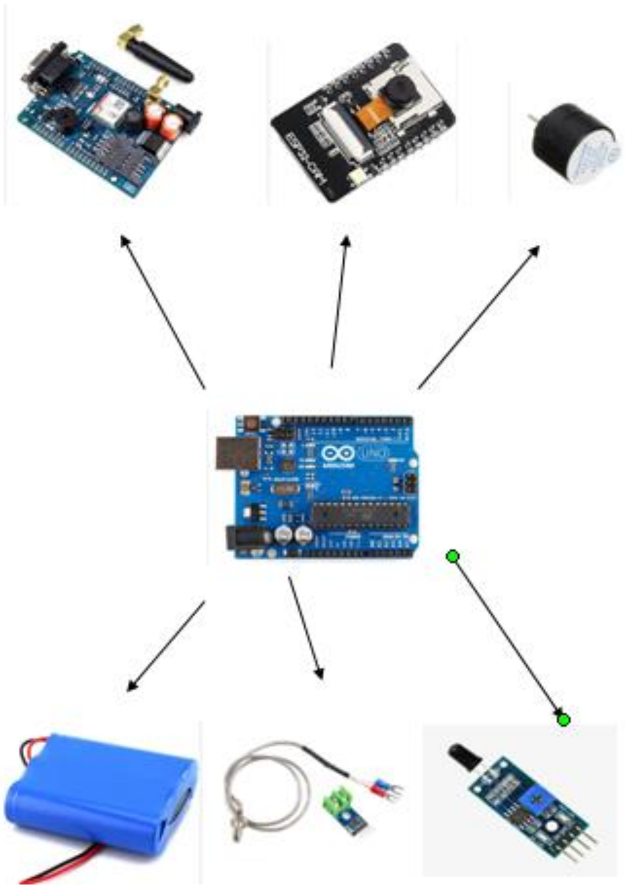
4.6 COMPONENT DIAGRAM:

A component diagram for the "Fire Detection System through IoT-Based Systems" project illustrates the structural relationships between the software components and their dependencies.

Key components include the IoT Sensor Module, which detects fire-related data, the Communication Module responsible for transmitting data to the Central Control System, and the User Interface Module, which provides real-time monitoring and control capabilities.

The Data Storage Module manages historical data for analysis, while the Alert System component triggers notifications to firefighters. This diagram highlights the interactions and interfaces between these components, ensuring seamless data flow and effective Fire Detection response.

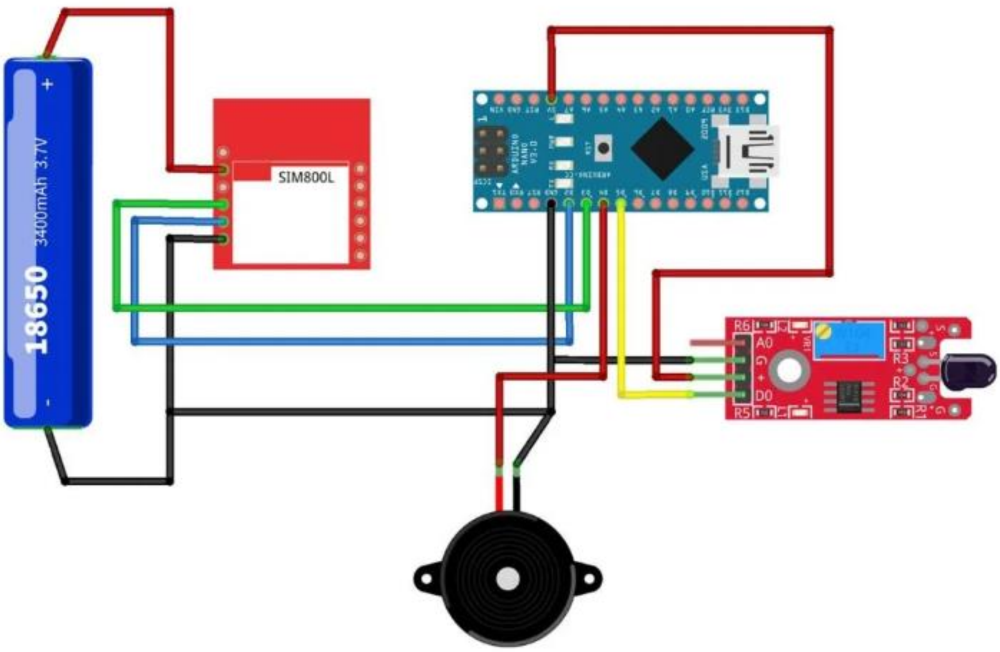
Figure 4.6 Component diagram



4.7 Circuit Diagram

A circuit diagram for the "Fire Detection System through IoT-Based Systems" project showcases the electrical connections and components essential for the system's functionality. The IoT Sensor Circuit includes flame sensors, smoke detectors, and temperature sensors connected to an Arduino UNO microcontroller, which processes the sensor data. The Communication Circuit integrates a Wi-Fi or GSM module to transmit data to the central server. Actuator Circuits, such as water pumps and servo motors, are controlled by the microcontroller to initiate Fire Detection actions. The Power Supply Circuit ensures stable power delivery to all components, and the Indicator Circuit uses LEDs and buzzers to signal alerts. This diagram provides a clear representation of how these circuits work together to enhance Fire Detection efficiency.

Figure 4.7 Circuit Diagram

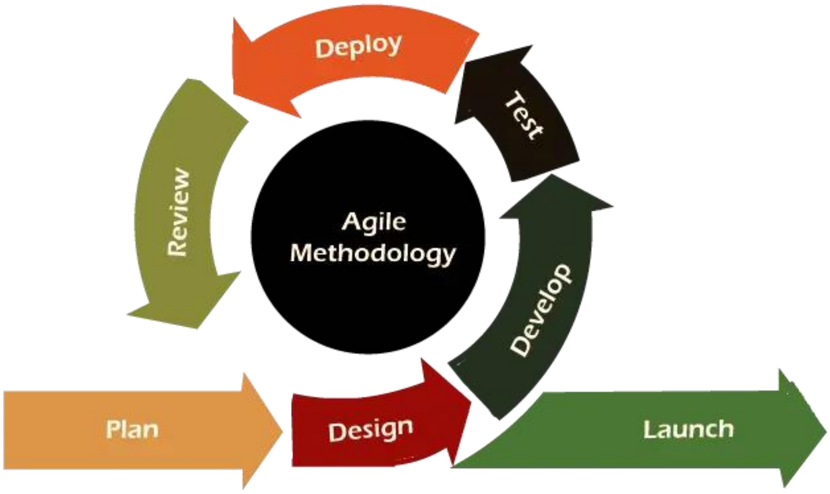


CHAPTER 5

IMPLEMENTATION AND TESTING

5.1 Implementation Approaches:

Agile Approach:
Agile is a flexible, iterative methodology for software development that emphasizes adaptability, collaboration, and incremental progress. Instead of delivering the complete system at the end, Agile breaks the project into manageable iterations or sprints, each focusing on a functional aspect of the system. For a project like "Fire Detection System through IoT," Agile allows teams to experiment with IoT components, implement fire detection features, and refine alert mechanisms incrementally. Agile principles such as prioritizing functional outcomes and fostering team collaboration ensure the project aligns with user requirements and accommodates technological challenges.



Agile Life Cycle for Fire Detection System through IoT -Based Systems:

1. Concept/Initiation
    - Developing an IoT-based system for fire detection and efficient response.
    - Identify stakeholders such as fire departments, building managers, and end-users.
    - Establish high-level requirements:
    - Detecting based on fire and temperature thresholds.
    - Send real-time alerts to stakeholders.
    - Monitor system performance and ensure reliability.

2. Iteration Planning
    - Sensor integration for fire detection.
    - Communication module setup for alerts (e.g. GSM)
    - Testing and calibration of sensors.
    - User interface for monitoring the system.
    - Prioritize tasks based on critical functionality, starting with sensor and alert systems.

3. Design and Development
    - Prototype sensor setup and integration with the microcontroller.
    - Implement fire detection logic and alert mechanisms.
    - Develop a live stream through esp32 cam for user interaction.

4. Testing and Quality Assurance
    - Sensor functionality under different conditions.
    - Alert delivery under real-world scenarios.
    - Overall system performance and reliability.

5. Review and Feedback
    - Gather feedback and assess the system against user requirements.

6. Release/Deployment
    - Fire and heat detection module in the first release.
    - Alert communication system in the second release.
    - Camera live stream interface in the final release.

7. Retrospective
    - Effective team collaboration.
    - Areas for improvement (e.g., sensor calibration or coding practices).
    - Apply lessons learned to enhance subsequent sprints and refine the development process.

5.2 CODE LISTING:

Fire detection system:

```
#include <max6675.h>
const int flamePin1 = 11;  // First flame sensor (Floor 1)
const int thermoDO = 4;
const int thermoCS = 5;
const int thermoCLK = 6;
const int buzzerPin = 9;  // Buzzer pin

MAX6675 thermocouple(thermoCLK, thermoCS, thermoDO);

#define FLAME_DETECTED LOW  // Flame sensor returns LOW when flame is detected
#define FLAME_SAFE HIGH     // Flame sensor returns HIGH when no flame is detected
#define TEMP_THRESHOLD 30.0 // Temperature threshold in Celsius

bool fireDetected = false;  // Flag to track fire detection
unsigned long buzzerStartTime = 0;
const unsigned long BUZZER_LIMIT = 5000;  // **5 seconds buzzer limit**
```

```
void setup()
{
  pinMode(flamePin1, INPUT);
  pinMode(buzzerPin, OUTPUT);
  digitalWrite(buzzerPin, LOW); // Ensure buzzer is off initially
  Serial.begin(9600);  // Initialize serial communication
  Serial.println("AT+CSQ");  // Check signal quality
  delay(500);
}

void loop()
{
  int flameStatus1 = digitalRead(flamePin1);  // Read first flame sensor
  float temperature = thermocouple.readCelsius(); // Read temperature from
MAX6675

   /* Serial.print("Current Temperature: ");
    Serial.print(temperature);
    Serial.println(" °C");*/

  if (flameStatus1 == FLAME_DETECTED && temperature >=
TEMP_THRESHOLD && !fireDetected)
  {
    fireDetected = true;  // Set fire detected flag
    digitalWrite(buzzerPin, HIGH);  // Activate buzzer
    buzzerStartTime = millis();  // Record buzzer activation time
    triggerEmergencyProtocol("Fire and excessive heat detected at your house!
http://192.168.82.99 click here for camera footage");
  }

  // Stop the buzzer after 5 seconds
  if (fireDetected && (millis() - buzzerStartTime >= BUZZER_LIMIT))
  {
    digitalWrite(buzzerPin, LOW);  // Turn off buzzer
    fireDetected = false;  // Reset fire detection flag to allow future detection
  }

  delay(1000); // Delay to prevent excessive readings
}

void triggerEmergencyProtocol(String message)
{
  Serial.println("ATD+917304693810;");  // Trigger GSM Call
  sendSMS(message);
}

void sendSMS(String message)
{
  Serial.println("AT+CMGF=1");  // Set GSM module to text mode
  delay(1000);
```

```
    Serial.println("AT+CMGS=\"+917304693810\"\r");
    Serial.println(message);
    Serial.write(26);  // Send CTRL+Z (end of SMS)
    delay(1000);
  }


#include "esp_camera.h"
#include <WiFi.h>

#define CAMERA_MODEL_AI_THINKER // Has PSRAM

#include "camera_pins.h"

const char *ssid = "Enjoyyy";
const char *password = "11111111";

void startCameraServer();
void setupLedFlash(int pin);

void setup() {
  Serial.begin(115200);
  Serial.setDebugOutput(true);
  Serial.println();

  camera_config_t config;
  config.ledc_channel = LEDC_CHANNEL_0;
  config.ledc_timer = LEDC_TIMER_0;
  config.pin_d0 = Y2_GPIO_NUM;
  config.pin_d1 = Y3_GPIO_NUM;
  config.pin_d2 = Y4_GPIO_NUM;
  config.pin_d3 = Y5_GPIO_NUM;
  config.pin_d4 = Y6_GPIO_NUM;
  config.pin_d5 = Y7_GPIO_NUM;
  config.pin_d6 = Y8_GPIO_NUM;
  config.pin_d7 = Y9_GPIO_NUM;
  config.pin_xclk = XCLK_GPIO_NUM;
  config.pin_pclk = PCLK_GPIO_NUM;
  config.pin_vsync = VSYNC_GPIO_NUM;
  config.pin_href = HREF_GPIO_NUM;
  config.pin_sccb_sda = SIOD_GPIO_NUM;
  config.pin_sccb_scl = SIOC_GPIO_NUM;
  config.pin_pwdn = PWDN_GPIO_NUM;
  config.pin_reset = RESET_GPIO_NUM;
  config.xclk_freq_hz = 20000000;
  config.frame_size = FRAMESIZE_UXGA;
  config.pixel_format = PIXFORMAT_JPEG;  // for streaming
  //config.pixel_format = PIXFORMAT_RGB565; // for face detection/recognition
  config.grab_mode = CAMERA_GRAB_WHEN_EMPTY;
  config.fb_location = CAMERA_FB_IN_PSRAM;
```

```
  config.jpeg_quality = 12;
  config.fb_count = 1;

  // if PSRAM IC present, init with UXGA resolution and higher JPEG quality
  //                      for larger pre-allocated frame buffer.
  if (config.pixel_format == PIXFORMAT_JPEG) {
    if (psramFound()) {
      config.jpeg_quality = 10;
      config.fb_count = 2;
      config.grab_mode = CAMERA_GRAB_LATEST;
    } else {
      // Limit the frame size when PSRAM is not available
      config.frame_size = FRAMESIZE_SVGA;
      config.fb_location = CAMERA_FB_IN_DRAM;
    }
  } else {
    // Best option for face detection/recognition
    config.frame_size = FRAMESIZE_240X240;
#if CONFIG_IDF_TARGET_ESP32S3
    config.fb_count = 2;
#endif
  }

#if defined(CAMERA_MODEL_ESP_EYE)
  pinMode(13, INPUT_PULLUP);
  pinMode(14, INPUT_PULLUP);
#endif

  // camera init
  esp_err_t err = esp_camera_init(&config);
  if (err != ESP_OK) {
    Serial.printf("Camera init failed with error 0x%x", err);
    return;
  }

  sensor_t *s = esp_camera_sensor_get();
  // initial sensors are flipped vertically and colors are a bit saturated
  if (s->id.PID == OV3660_PID) {
    s->set_vflip(s, 1);        // flip it back
    s->set_brightness(s, 1);   // up the brightness just a bit
    s->set_saturation(s, -2);  // lower the saturation
  }
  // drop down frame size for higher initial frame rate
  if (config.pixel_format == PIXFORMAT_JPEG) {
    s->set_framesize(s, FRAMESIZE_QVGA);
  }

#if                              defined(CAMERA_MODEL_M5STACK_WIDE)                           ||
      defined(CAMERA_MODEL_M5STACK_ESP32CAM)
  s->set_vflip(s, 1);
  s->set_hmirror(s, 1);
```

```
#endif

#if defined(CAMERA_MODEL_ESP32S3_EYE)
  s->set_vflip(s, 1);
#endif

// Setup LED FLash if LED pin is defined in camera_pins.h
#if defined(LED_GPIO_NUM)
  setupLedFlash(LED_GPIO_NUM);
#endif

  WiFi.begin(ssid, password);
  WiFi.setSleep(false);

  Serial.print("WiFi connecting");
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("");
  Serial.println("WiFi connected");

  startCameraServer();

  Serial.print("Camera Ready! Use 'http://");
  Serial.print(WiFi.localIP());
  Serial.println("' to connect");
}

void loop() {
  // Do nothing. Everything is done in another task by the web server
  delay(10000);
}
```

5.3 Code Efficiency:

Efficient coding in the fire detection system ensures quick and reliable fire detection with minimal resource usage. Using conditional checks (if-else) ensures real-time responses to sensor inputs. Modular functions like trigger Emergency Protocol enhance code reusability and maintainability. Resource optimization is achieved by using lightweight communication commands with the GSM module. Defining constants (FLAME_DETECTED, FLAME_SAFE) improves readability and reduces hardcoding. By minimizing delays and redundant operations, the system maintains fast processing. Proper commenting aids in understanding and debugging. This efficient approach ensures that the IoT-based firefighting system operates reliably and adapts to real-world scenarios effectively.

Key Aspects of Code Efficiency in Fire Detection System:

1. **Performance:** Ensures rapid fire detection and immediate activation of alerts by optimizing sensor readings and minimizing processing delays.

2. **Resource Usage:** Reduces memory and power consumption by efficiently handling multiple sensors and GSM communication within limited IoT hardware capabilities.

3. **Readability and Maintainability:** Modular functions and clear comments enhance code organization, making it easier to update or debug the system in emergency scenarios.

4. **Scalability:** Supports integration of additional sensors or modules to monitor multiple locations without compromising detection speed or alert accuracy.

Importance of Code Efficiency:

Firefighting Efficiency through IoT, code efficiency is vital to ensure the system operates in real-time with minimal delays. Efficient code allows the IoT devices, such as fire detectors, buzzer, and heat sensors, to communicate seamlessly, quickly processing data to trigger immediate action when fire hazards are detected. Optimized code ensures that these devices perform consistently across different environments, reducing latency in emergency response times. By enhancing the efficiency of the code, the overall system can better manage resources, respond faster, and improve safety outcomes in fire emergencies.

5.3 Testing Approach

Testing is a crucial part of the Firefighting Efficiency through IoT project to ensure the system works as intended, providing reliable performance in critical situations. The testing approach involves Unit Testing, Integration Testing, and Field Testing, each focusing on different aspects of the system to ensure efficiency and reliability.

5.3.1 Unit Testing:

Unit testing focuses on individual components, such as fire sensors, buzzer, and heat sensors, ensuring they function correctly on their own. For example, testing the sensor's ability to detect smoke accurately or the water pump’s response to a signal. Unit testing can identify issues early, saving time and resources in the long run. Automated testing frameworks can be used to test these components individually, ensuring they are logically sound and efficient.

5.3.2 Integration Testing:

Integration testing examines how the components work together within the system. In the IoT firefighting system, this could involve testing how sensors communicate with the central control unit or how the water pump interacts with the alarm system. It ensures that different parts of the system operate smoothly together, reducing the risk of failure during real-world operations. Tools like network simulators and IoT-specific testing platforms can be used for these tests.

5.3.3 Field Testing:

Field testing involves testing the IoT system in real-world environments to evaluate its performance, reliability, and responsiveness. For the firefighting system, this means testing how the sensors detect fires in various environmental conditions and how quickly the system responds. Feedback from field testing helps uncover practical issues that may not have been apparent during previous stages and ensures that the system functions effectively in emergencies.

5.3.4 Beta Testing:

Beta testing is the final phase where the IoT firefighting system is deployed to a select group of real users or testing environments to gather feedback on its real-world performance. In this phase, the system would be tested under various conditions, such as different building layouts or fire scenarios, to assess its reliability and responsiveness. Beta testers may report issues like delays in alert notifications, sensor malfunctions, or network connectivity problems.

5.5 Test Cases

Test Case	**Description**	**Expected Outcome**	**Result**
T1	Fire and heat detected by sensor	Alert sent via SMS/call to owner Activates buzzer	Pass
T2	No fire detected	System remains in standby mode	Pass
T3	No heat detected	System remains in standby mode	Pass
T4	GSM module fails	Retry mechanism initiated for sending the alert	Fail
T5	Only Heat detected below a certain range	System remains in standby mode	Pass
T6	Fire and heat detected by sensor	System fails to trigger call or notification	Fail
T7	ESP32-CAM fails to stream video	System should retry or send a warning message	Fail
T8	SMS alert sent, but user doesn't receive it	SMS alert sent, but user doesn't receive it	Fail
T9	False alarm triggered (sensor malfunction)	System should verify before sending an alert	Pass
T10	GSM module receives incorrect response from the network	System should attempt to resend message	Pass

CHAPTER 6

Chapter 6: Results and Discussion

6.1 Test Reports:

6.1.1 Overview

The fire detection system was tested under various conditions to ensure its accuracy, reliability, and responsiveness. The test cases focused on different fire scenarios, environmental factors, and system performance. The results demonstrate that the system effectively detects fire and triggers alerts in real time.

6.2 User Documentation:

6.2.1 Overview

The Fire Detection System is designed to detect fire hazards in real-time using IoT-based sensors. This section provides a detailed explanation of the system's functions, components, and usage instructions.

➢ **System Components**

- Flame Sensor - Detects presence of flames.
- Temperature Sensor (MAX6675 Module + K Type Thermocouple Sensor) - Measures temperature to identify fire hazards.
- 5v active buzzer - for alarm as soon as fire detects
- Arduino Uno- Microcontroller for data processing.
- Esp32 cam - for accessing camera
- Breadboard
- Gsm module - for calls and messages

6.2.3 System Workflow:

Step 1: System Initialization

- The **Arduino Uno** starts and initializes all components (Flame Sensor, Temperature Sensor, ESP32-CAM, GSM Module, Buzzer, etc.).
- The system remains in **standby mode**, continuously monitoring fire and temperature data.

Step 2: Fire and Heat Detection

- The **Flame Sensor** detects fire by sensing infrared light.
- The **Temperature Sensor (MAX6675 + K-Type Thermocouple)** measures ambient temperature.
- The system checks if both conditions are met:
    - **Flame detected**
    - **Temperature ≥ 30°C**

Step 3: Alert Triggering

- If **both conditions** are met:
    1. **Buzzer** is activated to sound an alarm. 🔊
    2. **GSM Module** sends an **SMS alert** and makes a **call** to the user. 📱
    3. The **SMS contains a link** to access the real-time camera feed from the **ESP32-CAM**.

Step 4: User Access & Response

- The user receives the **SMS alert** with the camera access link.
- The user checks the **live feed** to assess the fire situation remotely.
- If the fire is confirmed, the user can **take immediate action** (e.g., notify emergency services).

Step 5: System Monitoring & Recovery

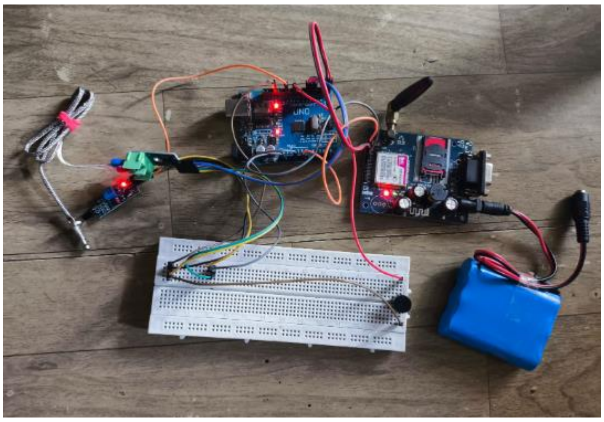
- If the fire **subsides**, the system **resets** and continues monitoring.
- If the fire persists, alerts are **repeated** until action is taken.
- If the **GSM module fails**, a **retry mechanism** is initiated to ensure message delivery.

Step 6: Power Backup Handling

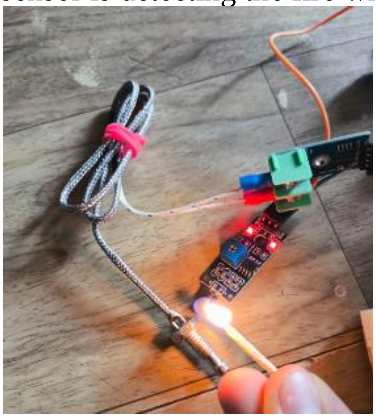
- If **power loss** occurs, the **12V Li-ion Battery** provides backup power to keep the system running.
- The system continues operating without interruption.

6.3 Step-by-Step Result with Screenshots

- Fire detection system: This is the overall IoT system of our Fire detection system through IoT based.

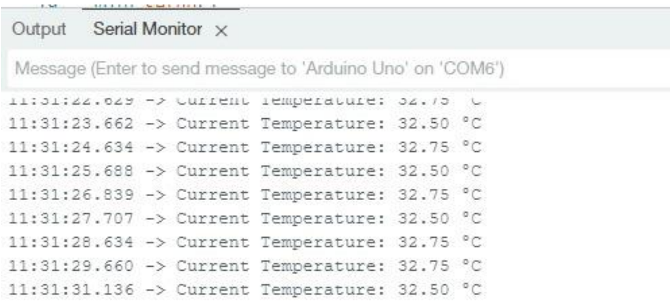


- Detecting fire : In this the sensor is detecting the fire which we emitted.



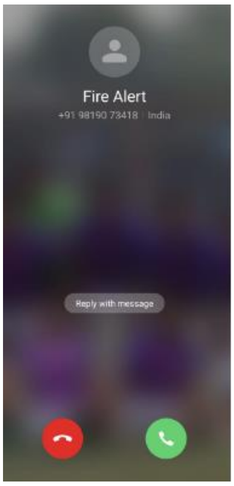
.

- Detecting temperature(serial monitor arduino ide): This is the serial monitor screen where it would detect the temperature of the current environment.

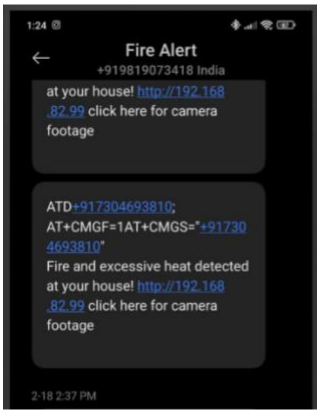


- Detecting heat as well as fire(serial monitor arduino ide): This would detect the heat as well as fire for detection.

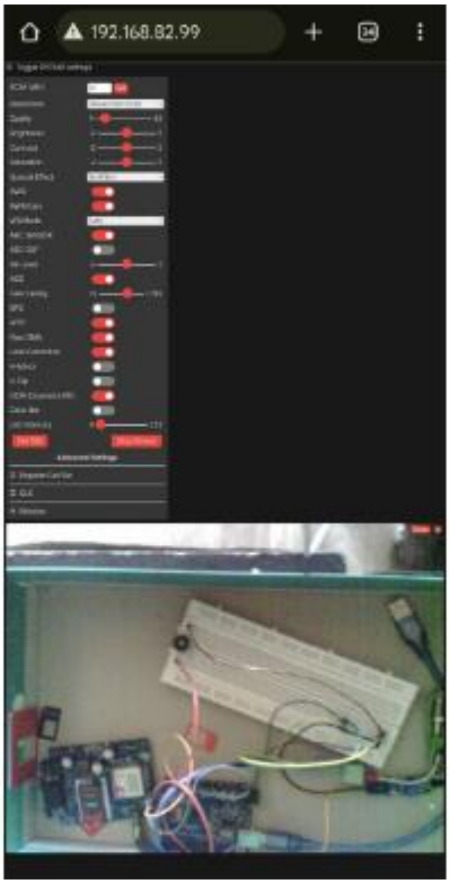
- Shows fire alert call: An alert call would come when the fire takes place.



- Fire Alert Notification: The notification would come as a pop up message as well as it would give the access to your camera.



- Live camera feed: This is the camera access where you would check all the feeds where the exact fire has taken place



CHAPTER 7

Conclusion

The Fire Detection System developed in this project effectively detects fire hazards in real-time and provides immediate alerts through IoT-based sensors. The system was tested under various conditions, demonstrating its ability to respond to fire incidents efficiently. With components such as flame, smoke, and temperature sensors integrated with a microcontroller and cloud-based dashboard, the system ensures continuous monitoring and quick notifications. However, some limitations were observed, including occasional false alarms, sensor malfunctions, and GSM module failures, which affected the system's overall reliability. Despite these challenges, the system has proven to be a valuable solution for fire detection and can be further enhanced by incorporating AI-based predictive analysis, improved sensor calibration, and additional communication methods like mobile app notifications. Future advancements may also include integrating the system with automated fire response mechanisms, making it more effective in preventing fire-related damage. With continuous improvements, this Fire Detection System has the potential to become a reliable and scalable fire safety solution for homes, offices, and industrial environments.

7.2 Limitations of the System:

Despite its effectiveness, the system has certain limitations:

- False Positives: The system sometimes triggers false alarms due to environmental factors like dust or high ambient temperatures.

- Limited Connectivity: The GSM module occasionally fails to send alerts due to network issues.

- Power Dependency: The system requires a stable power supply; power failures could affect its performance.

- Hardware Sensitivity: The sensors are susceptible to degradation over time, affecting accuracy.
  These limitations were noted during testing and demonstration sessions, and some aspects could not be modified due to hardware constraints and project scope.

Future Scope of the Project

1. AI-Based Fire Prediction:

   By integrating machine learning models, the system can analyze past sensor data and environmental conditions to predict potential fire hazards. AI algorithms can identify patterns that indicate early fire risks, allowing preventive actions. This approach enhances fire detection accuracy and reduces false alarms. Additionally, AI-driven analytics can suggest safety measures to mitigate risks. Over time, the model improves by learning from real-world incidents, making fire prediction more reliable.

2. Advanced Communication Mechanisms:

Implementing communication protocols like LoRaWAN or NB-IoT enhances alert transmission even in remote or low-connectivity areas. These technologies offer long-range, low-power communication, ensuring timely alerts without relying on cellular networks. This improves system reliability in rural and industrial locations where connectivity is limited. By integrating these mechanisms, the fire detection system remains functional in critical situations. It also reduces operational costs by minimizing dependence on expensive communication networks.

3. Battery Backup Integration:

Adding an uninterrupted power supply ensures that the fire detection system remains operational during power failures. A rechargeable battery backup provides continuous power, allowing sensors and alarms to function without disruption. This is crucial in emergency situations where electricity supply may be compromised. Implementing energy-efficient components can extend battery life, ensuring prolonged operation. A well-designed backup system enhances reliability and prevents system downtime.

4. Cloud-Based Data Analytics:

Integrating cloud-based analytics enables real-time monitoring and predictive insights for fire prevention. Sensor data is uploaded to the cloud, where AI models analyze trends and detect potential fire risks. This allows users to access reports and alerts from anywhere, improving decision-making. Predictive analytics can also help optimize fire safety measures based on historical data. A cloud-based system ensures scalability, supporting multiple devices and large-scale monitoring.

CHAPTER 8

CHAPTER 8
COST BENEFIT ANALYSIS

Introduction

The cost-benefit analysis evaluates the financial feasibility of implementing the Fire Detection System through IoT. This analysis considers both development costs and long-term benefits such as increased safety, reduced fire damage, and real-time monitoring.

COST EVALUATION

1. Software Costs:

• Since Arduino IDE are freely available, there are no direct software costs associated with acquiring these tools.

2. Development Costs:

• The system was developed by two developers, and the cost is calculated as follows:

Parameter	Value
Charges per day	Rs. 200
No. of Developers	2
No. of Days	120
Total Cost Calculation	2 × 200 × 120
Total Developer Cost	Rs. 48,000

• Development costs also include research and prototype development, which may require additional sensors and testing materials, adding approximately Rs. 5,000 to the total.

3. Hardware Costs:

Component	Total Cost (Rs.)
Flame Sensor	30
Temperature Sensor (MAX6675 + K-Type Thermocouple)	200
5V Active Buzzer	15
Arduino Uno	700
ESP32-CAM (Camera Module)	500
GSM Module (For Alerts)	600
Breadboard	50
Jumper Wires (Pack)	15
ESP32-CAM-MB Micro USB	500
Total Hardware Cost	Rs. 2,610

4. Testing and Maintenance Costs:
• The system was tested for real-world fire detection scenarios, including:
- Simulating fire conditions using controlled heat sources
- Testing sensor response time
- Checking network connectivity of ESP32 and GSM module

• Estimated testing and maintenance cost is calculated as:

Parameter	Value
No. of Hours per Day	2
Charges per Hour	Rs. 50
No. of Days	15
Total Cost Calculation	2 × 50 × 15
Total Testing and Maintenance Cost	Rs. 1,500

Total Cost Estimation:

Category	Cost (Rs.)
Development Cost	48,000
Hardware Cost	2,610
Testing and Maintenance Cost	1,500
Overall Estimated Cost	Rs. 52,110

BENEFITS OF IMPLEMENTATION

Although the system involves an initial investment, it provides long-term benefits such as:
1. Early Fire Detection - Reduces fire-related losses and enhances safety.
2. Remote Monitoring - Users can access real-time camera feed and alerts from anywhere.
3. Automated Emergency Response - Sends SMS and calls via the GSM module to emergency contacts.
4. Scalability - Can be integrated with IoT-based smart home or industrial safety systems.
5. Cost Savings - Reduces expenses on fire recovery, insurance claims, and infrastructure damage.

The Fire Detection System through IoT is an economical and efficient solution for fire safety. The total estimated cost of Rs. 52,110 is a one-time investment that offers long-term safety benefits. By leveraging IoT technology, cloud monitoring, and automation, this system provides a highly scalable and effective fire prevention solution.

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Research Paper

Fire Detection System Through IoT-Based

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Abstract: The efficiency of Fire Detection System operations is often hindered by delayed detection, inefficient resource allocation, and communication breakdowns during emergencies. Traditional fire detection systems are typically inadequate in providing early warnings, thereby increasing the risks for both firefighters and building occupants. This project aims to enhance Fire Detection System efficiency through the integration of Internet of Things (IoT) technology into existing systems. By deploying IoT-enabled sensors, wearables, and smart devices, it has been proposed that a robust real-time notification system that significantly improves monitoring, automated alerts, and communication. The methodology involves the design and implementation of a comprehensive IoT based Fire Detection System incorporating various sensors for real-time detection of smoke, heat, and hazardous gases, establishing a reliable communication network, and implementing an automated alert system. Additionally, data analytics tools will process the collected data to gain insights into incident patterns and the effectiveness of responses. This research is expected to enhance the safety and efficiency of Fire Detection System operations, ultimately reducing casualty rates and property damage. The author that has proposed system leverages cloud-based platforms and machine learning algorithms to ensure scalability and adaptability, making it a sustainable solution for diverse Fire Detection System scenarios. The integration of mobile devices for real-time notifications further ensures that all stakeholders are promptly informed, enabling swift and coordinated emergency responses.

Keywords: Fire Detection System Efficiency, IoT, Real-Time Notification System, Automated Alerts, Sensor Deployment, Communication Network, Data Analytics, Emergency Response, Safety.[1]

INTRODUCTION

Recent advancements in Internet of Things (IoT) technology are driving significant innovations across various sectors, including public safety and emergency services. In the context of Fire Detection System , IoT offers transformative potential by introducing new methodologies to enhance operational efficiency and response effectiveness. Traditional Fire Detection System methods often face challenges such as delayed detection, limited situational awareness, and inefficient resource management. These challenges can result in increased response times, higher risks to firefighters, and greater damage to property and lives. By integrating IoT technologies, Fire Detection System operations can overcome these limitations through real-time monitoring, predictive analytics, and automated response mechanisms. IoTenabled systems provide continuous data collection from various sensors, allowing for early detection of fire hazards and improved situational awareness. This proactive approach not only enhances the safety of firefighters but also ensures a more efficient allocation of resources and faster response times.[2]

I. LITERATURE SURVEY

1) **Lorenzo Rossi**
   Book: "Smart Sensors and IoT for Smart Cities"
   Description: Rossi focuses on the integration of smart sensors and IoT in urban environments, including their use in emergency response systems like Fire Detection System for better efficiency and effectiveness.
2) **R. K. Gupta**
   Book: "Internet of Things and Cloud Computing: A Comprehensive Guide"
   Description: Gupta's book provides an overview of IoT and cloud computing technologies, detailing how they can be applied to enhance Fire Detection System operation and improve efficiency.
3) **S. B. Shanthini**

Book: "IoT and Machine Learning for Smart Cities"
Description: This book discusses how IoT and machine learning can improve smart city infrastructure, including emergency services like Fire Detection System , by enhancing operational efficiency.'

4) **Mubarak Shah**
Book: "Computer Vision for Assistive Technologies"
Description: Shah explores the application of computer vision and AI in various technologies, including safety and monitoring systems, which are relevant to IoT-based Fire Detection.[3]

II. PROPOSED MODEL

The proposed model for enhancing Fire Detection System efficiency through IoT integration focuses on leveraging advanced technologies to address current challenges in Fire Detection System operations. Central to the model is the deployment of a comprehensive IoT infrastructure consisting of sensors, communication networks, and data analytics capabilities.

A. Key Characteristics:

1. Real-time Monitoring**:** Continuous monitoring of environmental conditions such as temperature, smoke levels, and air quality using IoT sensors to provide early detection of fire incidents.
2. Predictive Analytics: Utilization of data analytics and machine learning algorithms to analysis historical and real-time data, predicting potential fire hazards and optimizing Fire Detection System strategies.
3. Automated Response: Integration of automated control systems that can activate Fire Detection System equipment (e.g., sprinklers, extinguishers) based on real-time sensor data, reducing response times and minimizing damage.
4. Remote Monitoring and Control: Ability to monitor and control Fire Detection System operations remotely via IoT-enabled devices, ensuring timely adjustments and interventions as needed.
5. Scalability and Adaptability: Designing the system to be scalable and adaptable to various Fire Detection System scenarios and environments, accommodating different building layouts and emergency situations effectively.[4]

III. METHODOLOGY

The methodology for implementing IoT in Fire Detection System begins with identifying operational requirements and selecting appropriate sensors for real-time data collection. Data is transmitted via secure networks to a central hub for processing using machine learning algorithms for predictive analysis of fire risks. Automated response systems are then activated based on these insights, controlling Fire Detection equipment remotely to minimize response times. Cloud infrastructure supports scalable data storage and computation, ensuring robust performance. Rigorous testing in controlled and live environments validates system reliability and effectiveness. Continuous iteration and feedback refine algorithms and operational procedures. Collaboration with Fire Detection System experts ensures alignment with industry standards and operational needs, optimizing the IoT system for enhanced Fire Detection System efficiency.[5]

IV. TECHNOLOGY ADOPTED

A. Frontend Features

1. Real-time Data Visualization**:** Displaying live sensor data such as temperature, smoke levels, and fire alerts in a clear and actionable format, using charts, graphs, and visual indicators.
2. Interactive Maps**:** Integrating geospatial data to visualize the location of sensors, incidents, and deployed Fire Detection System resources, aiding in strategic decision-making and resource allocation.
3. Alerts and Notifications**:** Implementing real-time alerts and notifications via SMS, email, or push notifications to inform firefighters and emergency responders about critical incidents and updates.
4. Responsive Design**:** Ensuring the interface is responsive and accessible across different devices and screen sizes, crucial for usability in dynamic Fire Detection System environments.
5. User Authentication and Access Control**:** Implementing secure login mechanisms and rolebased access control (RBAC) to safeguard sensitive data and ensure only authorized personnel can access and manage the system.

6. *Backend Features*

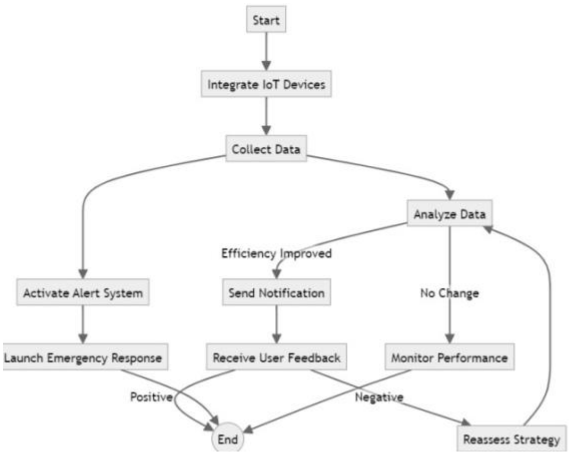
Data Processing and Storage: Implementing robust systems for storing and managing large volumes of sensor data collected in real-time from Fire Detection System equipment and IoT devices.

Data Analytics**:** Utilizing machine learning algorithms and statistical analysis to process sensor data, identify patterns, and predict potential fire incidents or anomalies.

7. *AI Technologies*

AI technologies play a critical role in revolutionizing Fire Detection System efficiency through IoT integration. These technologies enable predictive analytics, leveraging machine learning algorithms to analyse vast amounts of data from IoT sensors. By identifying patterns and anomalies, AI can predict potential fire outbreaks with greater accuracy, allowing Fire Detection System teams to deploy resources and mitigate risks before emergencies escalate. Natural Language Processing (NLP) facilitates efficient communication and decision-making by interpreting textual data, such as incident reports and maintenance logs. Computer vision systems enhance situational awareness by analysing visual data from cameras and drones, detecting fire hazards and monitoring environmental conditions in real-time.[6]

V. FLOW DIAGRAM



VI. FUTURE SCOPE

The future scope of integrating AI and IoT in Fire Detection System includes advancing predictive models for more accurate fire detection, enhancing AI-driven automation for faster emergency response, integrating augmented reality for real-time situational visualization, developing autonomous Fire Detection System drones for remote operations, exploring blockchain for secure data management, and expanding AI-driven analytics for continuous improvement in Fire Detection System strategies and safety protocols.[7]

Conclusion

In conclusion, AI and IoT technologies are revolutionizing Fire Detection System by enabling proactive fire detection, swift response times, and optimized resource allocation. These advancements enhance operational efficiency and safety outcomes, crucial in mitigating risks and minimizing damage during emergencies. Future developments in augmented reality and autonomous systems promise further advancements in Fire Detection System capabilities. Continued focus on data security and analytics will ensure the reliability and effectiveness of these technologies in real-world applications. Ultimately, the integration of AI and IoT not only improves emergency response but also sets the stage for safer and more resilient Fire Detection System practices, shaping the future of public safety worldwide.

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