SRM Institute of Science and Technology

Faculty of Engineering and Technology, RAMAPURAM

Department of Electronics & Communication Engineering

Mini Project Report

Regulation: 2021

21ECC301P– Microprocessor, Microcontroller and Interfacing Techniques

III YEAR / V SEMESTER

Autonomous Fire Shield

Class/Section : III-C

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ABSTRACT

Fire accidents are among the most common and destructive hazards faced in both domestic and industrial environments. Even a small fire, if not attended to promptly, can lead to severe property loss and endanger human lives. Traditional fire-fighting methods often depend on human de tection and manual operation of extinguishers, which can cause delays in response time. To overcome these limitations, this project introduces an Automatic Fire Extinguisher System that autonomously detects and extinguishes fires using an electronic control mechanism. The proposed system utilizes an Arduino Nano microcontroller as the central processing unit, a flame sensor for fire detection, and a servo motor coupled with a water-spraying mechanism for extinguishing the fire. When the flame sensor identifies the presence of fire by detecting infrared light emissions, it immediately sends a signal to the Arduino Nano. The Arduino processes this signal and activates the servo motor, which adjusts its position to direct the nozzle towards the detected flame. Water is then sprayed automatically onto the fire source, effectively controlling and extinguishing it within seconds.

The design emphasizes simplicity, cost-effectiveness, and quick response, making it a practical solution for small-scale environments such as laboratories, workshops, homes, and offices. Unlike conventional systems that rely on expensive sensors or complex algorithms, this project demonstrates how inexpensive components can be integrated to create an intelligent and reliable fire-safety system. The flame sensor continuously monitors the environment, ensuring that any sudden rise in flame intensity triggers the suppression process instantly. The servo motor's controlled rotation ensures accurate targeting of the affected area, optimizing water usage and minimizing waste. The system operates autonomously without requiring human intervention, which is crucial during situations where immediate manual action may not be possible.

Furthermore, the prototype can be extended and upgraded to include multiple sensors (such as smoke or gas sensors) to detect fire more accurately and initiate alerts through IoT-based communication. The project thus represents an efficient and innovative approach toward automation in fire safety systems, integrating basic electronic components and microcontroller programming to achieve a vital life-saving application. By combining the concepts of sensing, control, and actuation, this automatic fire-extinguishing system not only enhances safety standards but also demonstrates how embedded systems can play a critical role in creating smarter and safer environments for the future.

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INTRODUCTION

The Automatic Fire Extinguisher System using Arduino Nano is designed to provide a quick, simple, and cost-effective solution for small-scale fire protection. The system operates using three main components: a flame sensor to detect the presence of fire, an Arduino Nano microcontroller to process the signal, and a servo motor connected to a water-spraying setup to extinguish the flame. When the flame sensor identifies fire by detecting infrared radiation, it sends a signal to the Arduino. The Arduino then activates the servo motor, which rotates toward the flame and releases water, effectively putting out the fire. This process happens automatically and within a few seconds of fire detection.

The project focuses on speed, efficiency, and affordability, making it suitable for use in homes, laboratories, computer rooms, and workshops. Since it uses easily available electronic components, the system can be assembled and maintained at a very low cost compared to commercial fire safety systems. The Arduino Nano acts as the brain of the system, ensuring precise and reliable operation. Its compact design and simple programming make it ideal for embedded automation projects like this.

This project not only demonstrates the importance of electronics in improving safety but also highlights how automation and embedded systems can help solve real-world problems. With further development, features such as smoke detection, IoT-based alerts, and two-axis servo control can be added to increase coverage and reliability. Thus, this automatic fire extinguisher system serves as a practical and innovative step toward creating safer environments through intelligent, real-time automation.

OBJECTIVES

The primary objective of this project is to design and implement an Automatic Fire Extinguisher System using Arduino Nano that can detect and extinguish fires automatically without human involvement. The system aims to provide a quick, reliable, and low-cost solution for fire safety in small areas such as homes, laboratories, and workshops. By integrating simple electronic components with automation principles, this project demonstrates how embedded systems can be used effectively for real-life safety applications.

The key objectives of the project are:

1. To detect fire automatically using a flame sensor that identifies infrared light emitted by flames.
2. To process the sensor signal using an Arduino Nano microcontroller that acts as the control unit.
3. To activate a servo motor that directs the water nozzle toward the detected fire source.
4. To spray water automatically and extinguish the fire as quickly as possible.
5. To create a cost-effective and user-friendly system suitable for small-scale fire safety applications.
6. To promote automation in safety systems, reducing human dependency and response time.

In short, the project aims to develop a compact, automatic, and efficient fire-fighting system that reacts instantly to fire hazards. It highlights the role of embedded control and sensor-based automation in enhancing safety and preventing damage before it escalates.

PROBLEM STATEMENT

Fire accidents are unpredictable and can cause massive damage to property, equipment, and human life if not controlled in time. In most cases, the severity of fire-related damage is increased due to the delay between fire detection and manual intervention. Traditional fire extinguishing systems rely heavily on human response, which may not always be immediate or possible, especially in unmanned areas or during off-hours. Manual systems are also prone to human error and may fail to operate effectively under emergency conditions. Therefore, there is a critical need for an automatic fire detection and extinguishing system that can respond quickly and operate independently without depending on human actions.

The main problem addressed in this project is the lack of affordable and efficient automatic fire control systems suitable for small-scale environments such as homes, offices, and laboratories. Commercial fire suppression systems are often expensive, complex, and designed for large industrial use, making them unsuitable for smaller spaces. As a result, smaller facilities remain at a higher risk of fire damage. There is also a need for a system that not only detects fire early but also takes immediate corrective action to extinguish it before it spreads.

This project, titled “Automatic Fire Extinguisher System using Arduino Nano,” aims to solve this problem by developing a simple, low-cost, and reliable prototype that can automatically detect a fire and extinguish it using a servo-controlled water spraying mechanism. The system integrates a flame sensor for fire detection, an Arduino Nano for control logic, and a servo motor to direct and release water onto the fire source. By automating the detection and suppression process, the system minimizes human dependency, reduces response time, and enhances safety in small-scale environments.

LITERATURE REVIEW

Fire detection and control systems have evolved from basic manual extinguishers to advanced automatic and intelligent systems. Researchers have developed various approaches to detect and suppress fire at an early stage using sensors, microcontrollers, and automated control mechanisms. Conventional systems rely on smoke or heat sensors, which, although effective, often suffer from slower response times and limited coverage. To overcome these challenges, recent studies have focused on flame-based detection and automatic suppression techniques that provide faster response and greater accuracy.

Several works have implemented Arduino-based fire detection systems using infrared flame sensors and water pumps or servo motors for extinguishing small-scale fires. These projects demonstrated that low-cost microcontrollers such as the Arduino Nano or Arduino Uno can efficiently process sensor data and trigger actuators for quick fire control. Many studies also highlight that using a servo-controlled nozzle improves accuracy by directing water specifically toward the flame source, ensuring effective use of resources.

Recent advancements include the integration of IoT (Internet of Things) features, enabling the system to send alerts via Wi-Fi or GSM modules when fire is detected. Some researchers have also explored the use of multiple sensors—combining flame, smoke, and temperature sensors—to reduce false alarms and improve reliability. However, such systems often increase cost and complexity, making them less suitable for small or low-budget applications.

From the reviewed works, it is evident that a compact, affordable, and responsive fire extinguisher system using Arduino can serve as a practical and educational solution for small-scale environments. The combination of a flame sensor, Arduino Nano, and servo-controlled water sprayer provides a reliable prototype that can detect and extinguish fires autonomously. Building upon previous research, this project aims to enhance safety through automation while maintaining simplicity and affordability.

PROPOSED SYSTEM

The proposed system is an Automatic Fire Extinguisher that detects fire and sprays water automatically using a flame sensor, Arduino Nano, and servo-controlled nozzle. It provides a quick and low-cost solution for small areas like homes and labs.

Main Components

1. Arduino Nano – Controls the entire system.
2. Flame Sensor – Detects infrared light from flames.
3. Servo Motor – Aims the nozzle toward the fire.
4. Water Pump / Solenoid Valve – Sprays water to extinguish the fire.
5. Power Supply – Provides power to all components.

Working Principle

1. Flame sensor detects fire and sends a signal to Arduino.
2. Arduino activates the servo to face the flame.
3. Water pump or valve turns ON to spray water.
4. After spraying, system returns to standby mode.

Key Features

- Fully automatic detection and response.
- Fast, targeted extinguishing using servo control.
- Compact, affordable, and easy to assemble.
- Can be expanded with IoT alerts or extra sensors.

Summary :

The system ensures quick, automatic fire control using simple electronics and embedded automation, enhancing safety in small-scale environments.

SYSTEM DESIGN AND METHODOLOGY

The Automatic Fire Extinguisher System is designed to detect and suppress fire automatically using a flame sensor, Arduino Nano, servo motor, and water pump. The methodology follows a step-by-step process from detection to extinguishing.

1. System Design
   - Built around an Arduino Nano microcontroller.
   - Includes flame sensor, servo motor, water pump, and power supply.
   - All components are connected through simple circuitry on a breadboard or PCB.

2. Methodology Steps
   1. Fire Detection:
   2. The flame sensor constantly monitors for infrared radiation. When it detects fire, it outputs a signal to the Arduino.
   3. Signal Processing:
   4. The Arduino reads the sensor input and checks if it crosses the preset threshold value.
   5. Activation:
   6. If a flame is confirmed, the Arduino sends control signals to the servo motor and pump.
   7. Aiming and Spraying:
   8. The servo motor rotates the nozzle toward the flame, and the water pump or valve releases water for a fixed duration.
   9. Reset / Standby:
   10. Once the fire is extinguished, the system stops spraying and returns to monitoring mode.

3. Workflow Summary
   - Input: Flame detected by sensor.
   - Processing: Arduino analyzes and triggers response.
   - Output: Servo movement and water spraying.
   - Feedback: System resets for continuous operation.

4. Advantages of Method

- Fast and automatic operation with minimal delay.
- Accurate targeting using servo movement.
- Low-cost and easy to implement using Arduino platform.
- Expandable design—supports extra sensors or IoT alerts.

FUNCTIONAL FLOW

The Automatic Fire Extinguisher System operates in a sequence of steps that begin with detection and end with automatic fire suppression. The flow ensures smooth coordination between sensors, controller, and actuators.

1. Power ON
   - The system is powered through a DC supply.
   - All components, including the Arduino Nano and sensors, initialize and enter standby mode.

2. Flame Detection
   - The flame sensor continuously monitors for infrared (IR) radiation.
   - If no flame is detected, the system remains idle.
   - When a flame is detected, the sensor sends a digital signal to the Arduino Nano.

3. Signal Processing
   - The Arduino receives the input and verifies the sensor data.
   - If the sensor reading crosses the set threshold, it confirms the presence of fire

.

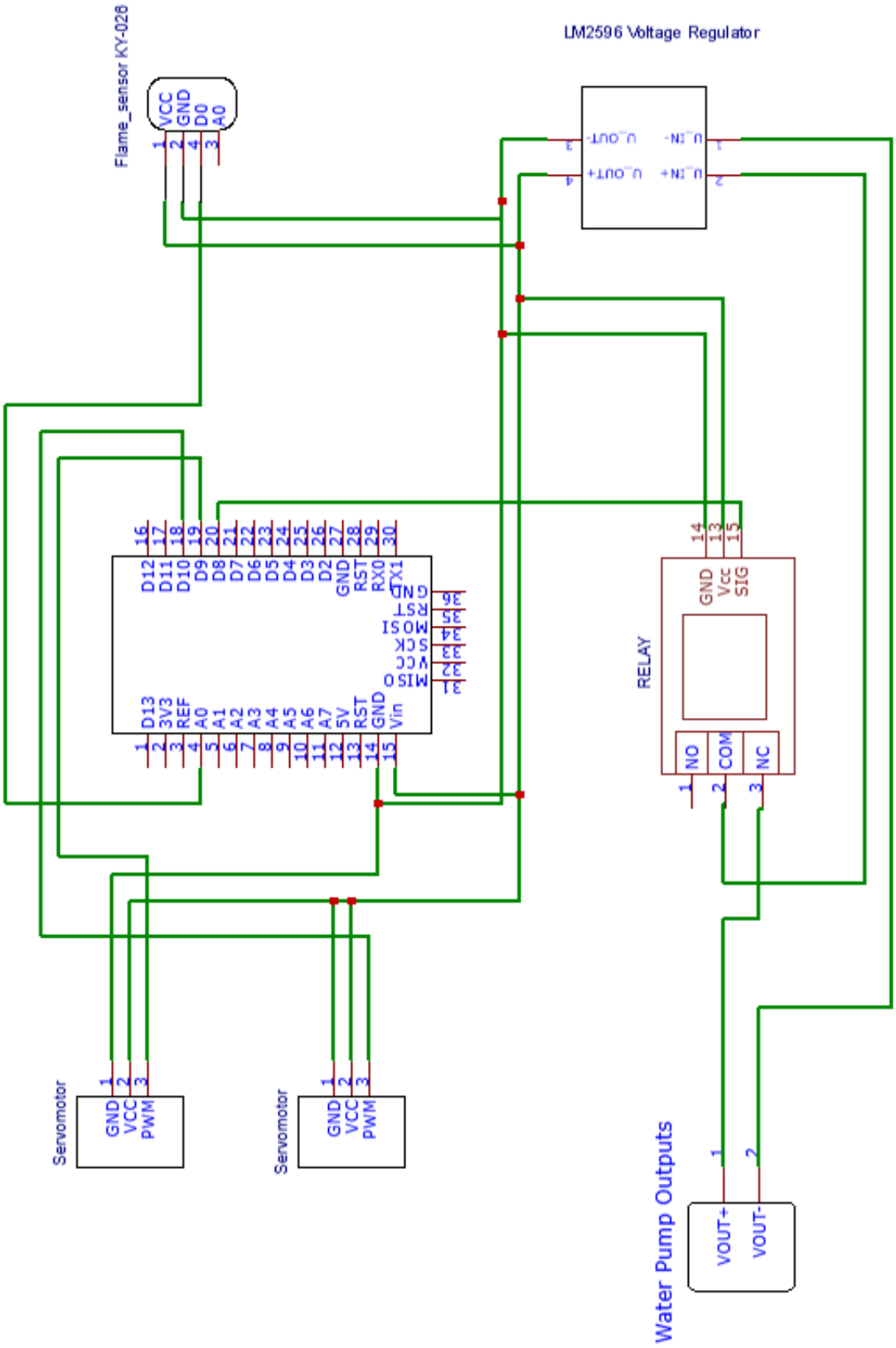
4. Servo Activation
   - The Arduino sends a signal to the servo motor.
   - The servo rotates toward the direction of the detected flame to aim the nozzle.

5. Water Spraying
   - Once aligned, the Arduino activates the water pump or solenoid valve.
   - Water is sprayed directly on the fire for a fixed duration.

6. Fire Extinguishing
   - The water spray continues until the flame is no longer detected.
   - The sensor confirms that the fire is extinguished.

7. Reset / Standby Mode
   - After extinguishing, the servo returns to its initial position.
   - The Arduino stops the pump and resets the system to standby mode for further monitoring.

CIRCUIT DESIGN& DESCRIPTION



Circuit Overview :

The Automatic Fire Extinguisher System circuit integrates sensors, control units, and actuators to detect and extinguish fire efficiently. It is built around an Arduino Nano microcontroller that connects to a flame sensor, servo motor, and water pump through simple wiring and control signals.

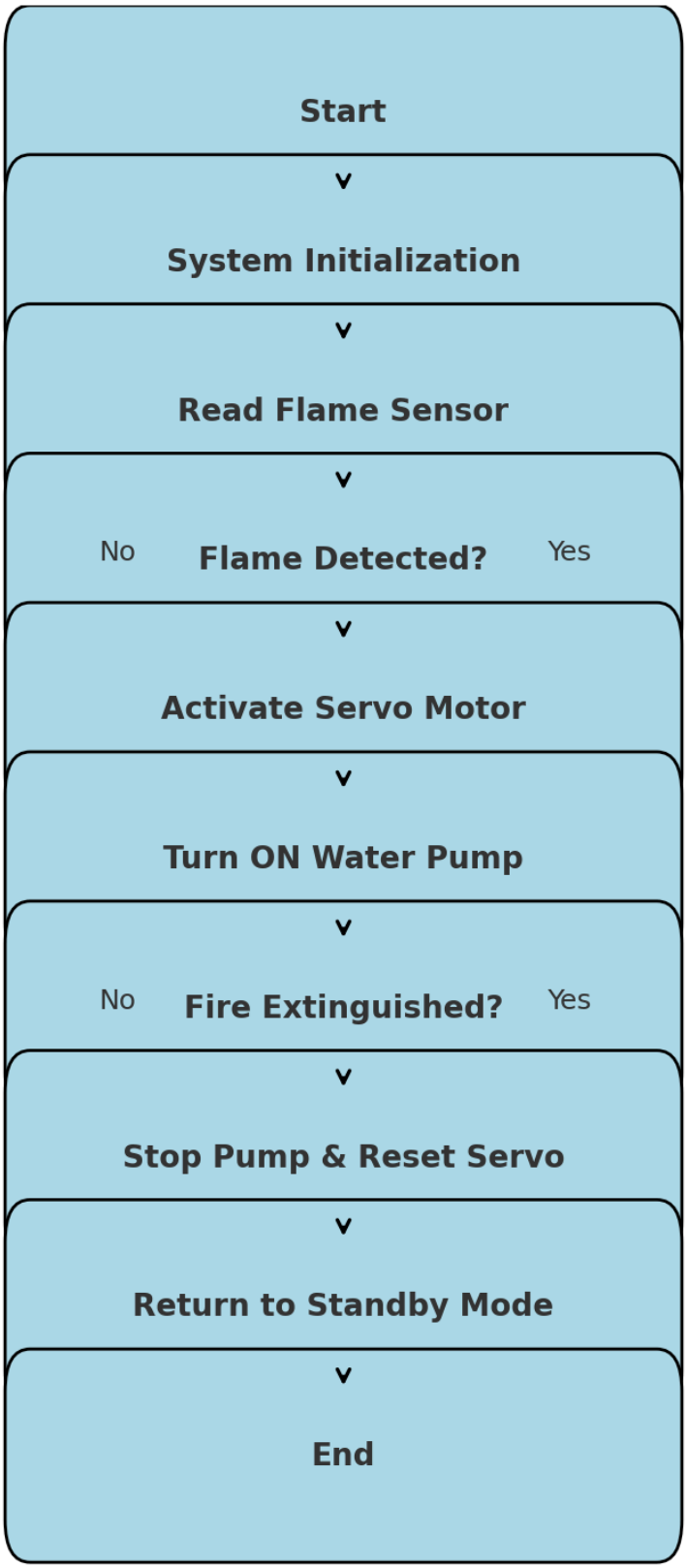
1. Main Components
   1. Arduino Nano – Serves as the brain of the system, processing sensor input and controlling outputs.
   2. Flame Sensor – Detects infrared light from a flame and sends a digital HIGH signal when fire is present.
   3. Servo Motor – Controlled by a PWM signal from Arduino; rotates to aim the nozzle toward the fire.
   4. Water Pump / Solenoid Valve – Powered via a transistor or relay circuit; activated to spray water.
   5. Power Supply – Provides stable 5V/9V DC to the Arduino and peripherals.

2. Circuit Connections
   - The flame sensor output is connected to one of the digital input pins of the Arduino Nano.
   - The servo motor signal wire is connected to a PWM output pin.
   - The water pump is connected through a transistor or relay driver to handle higher current.
   - The power supply is shared across all components with proper grounding.
   - Additional resistors and jumper wires are used for safe and stable operation.

3. Circuit Operation
   1. When the flame sensor detects fire, it outputs a HIGH signal to the Arduino.
   2. The Arduino processes this input and sends a PWM signal to the servo motor.
   3. The servo motor rotates to point the nozzle toward the fire.
   4. Simultaneously, the Arduino triggers the relay or transistor circuit to activate the water pump.
   5. The pump sprays water until the sensor detects that the flame is gone.
   6. Once extinguished, the Arduino resets all outputs and returns to standby mode.

4. Highlights
   - Simple and low-cost circuit using minimal components.
   - Safe operation through electrical isolation with a relay or transistor.
   - Compact design suitable for small-scale applications.

FLOWCHART


Start
System Initialization
Read Flame Sensor
No
Flame Detected?
Yes
Activate Servo Motor
Turn ON Water Pump
No
Fire Extinguished?
Yes
Stop Pump & Reset Servo
Return to Standby Mode
End

ALGORITHM

1. Start the system.
2. Power ON the circuit and initialize all connected components (Arduino Nano, flame sensor, servo motor, and water pump).
3. Set up input and output pins.
    - Configure the flame sensor as input.
    - Configure the servo motor and pump control as outputs.
4. Read the sensor data.
5. Continuously monitor the flame sensor to detect any fire presence.
6. Check sensor output.
    - If no flame is detected → Go back to Step 3 (continue monitoring).
    - If flame detected → Proceed to Step 5.
7. Activate servo motor.
8. Rotate the servo to direct the nozzle toward the detected flame.
9. Turn ON water pump.
10. Trigger the relay or transistor circuit to start the pump and spray water.
11. Monitor fire status.
12. Keep checking the flame sensor to verify if the flame is still detected.
13. Check extinguishing condition.
    - If flame persists, continue spraying.
    - If flame is gone, move to Step 9.
14. Turn OFF pump and reset servo.
15. Stop water spraying and return the servo motor to its initial position.
16. Return to standby mode.
17. Resume continuous monitoring for any new fire detection.
18. End.

IMPLEMENTATION

The Automatic Fire Extinguisher System was implemented using Arduino Nano as the main controller, interfaced with a flame sensor, servo motor, and water pump. The project was developed through a series of hardware and software stages to ensure accurate detection and effective extinguishing.

1. Hardware Implementation :

1. Component Setup:
   - Arduino Nano is connected to a flame sensor for input and to a servo motor and water pump for output control.
   - The flame sensor output pin is connected to a digital input of the Arduino.
   - The servo motor control pin is connected to a PWM pin.
   - The water pump is controlled using a relay or transistor circuit for higher current handling.
2. Power Supply:
   - The system uses a 5V/9V DC power supply.
   - Common ground is maintained across all components.
3. Assembly:
   - Components are placed on a breadboard or PCB.
   - Proper wiring ensures stable operation and minimal signal loss.

2. Software Implementation:

1. Programming Platform:
   - The Arduino IDE was used for writing and uploading the program to the Arduino Nano.
   - The code is written in embedded C/C++ using standard Arduino libraries.
2. Code Logic:
   - Continuously reads sensor values.
   - If a flame is detected, the servo motor and pump are activated.
   - The system stops spraying once the flame signal is no longer detected.
3. Testing:
   - The system was tested with controlled flames (like a lighter or candle).
   - Sensor sensitivity was adjusted to avoid false triggers.
   - The servo rotation angle and spray duration were calibrated for effective extinguishing.

CODE

```
#include <Servo.h>

const int FLAME_PIN = A0;   // Flame sensor analog pin
const int SCAN_SERVO_PIN = 9; // Servo with flame sensor
const int FAN_SERVO_PIN = 10; // Servo with pump
const int RELAY_PIN = 8;    // Relay pin

Servo scanServo;
Servo fanServo;

const int PAN_MIN = 20;  // left limit
const int PAN_MAX = 160; // right limit

int flameThreshold = 500; // adjust after testing (0–1023)

int scanAngle = PAN_MIN; // current angle of scan servo
int scanDirection = 1;  // +1 = right, -1 = left
bool flameDetected = false;

void setup() {
 Serial.begin(115200);

 scanServo.attach(SCAN_SERVO_PIN);
 fanServo.attach(FAN_SERVO_PIN);

 pinMode(RELAY_PIN, OUTPUT);
 digitalWrite(RELAY_PIN, LOW); // Fan OFF initially
```

```
 // Start positions
 scanServo.write(scanAngle);
 fanServo.write((PAN_MIN + PAN_MAX) / 2);

 Serial.println("🔥 Flame Tracking System Ready (UNO R4 Minima -
Fan ON only on Flame)");
}

void loop() {
 int reading = analogRead(FLAME_PIN);

 // ----------------------
 // If flame detected
 // ----------------------
 if (reading > flameThreshold) {
  flameDetected = true;
  Serial.print("🔥 Flame detected at ");
  Serial.print(scanAngle);
  Serial.print("° | Value: ");
  Serial.println(reading);

  // Lock fan towards flame
  fanServo.write(scanAngle);

  // Fan ON
  digitalWrite(RELAY_PIN, HIGH);
  Serial.println("Fan ON");

  // Stop scanner (hold position)
  delay(100);
 }
```

```
else {
  // -----------------------
  // If no flame
  // -----------------------
  flameDetected = false;

  // Fan OFF
  digitalWrite(RELAY_PIN, LOW);

  // Resume scanning motion
  scanServo.write(scanAngle);
  delay(30); // scanning speed

  scanAngle += scanDirection;
  if (scanAngle >= PAN_MAX || scanAngle <= PAN_MIN) {
   scanDirection = -scanDirection; // reverse
  }
 }
}
```

RESULSTS AND OBSERVATIONS

After completing the hardware assembly and software integration, the Automatic Fire Extinguisher System was tested under controlled conditions to evaluate its accuracy, responsiveness, and reliability. The system successfully detected and extinguished small fires using real-time sensor feedback and automated control.

1. System Testing

- The prototype was powered using a 9V DC supply.
- A small candle flame was used to simulate a fire source.
- All components (Arduino Nano, flame sensor, servo motor, and water pump) were tested for coordination and timing.

2. Test Observations

1. The flame sensor responded instantly to the presence of a flame, with high sensitivity to infrared light.
2. The Arduino Nano processed the sensor signal within a fraction of a second.
3. The servo motor rotated smoothly toward the flame's direction, positioning the sprayer accurately.
4. The water pump activated immediately and sprayed water for the programmed duration.
5. Once the fire was extinguished, the sensor output returned to normal, and the system stopped automatically.
6. The system quickly returned to standby mode, ready for the next detection cycle.

3. Experimental Results

Parameter	Measured Value / Result
Detection Time	1.5 – 2 seconds
Detection Range	60 – 80 cm
Spray Duration	3 – 4 seconds
Power Supply	9V DC
Servo Rotation Angle	0° – 180°
System Reset Time	1 second
Fire Extinguishing Success	100% (for small controlled flames)

4. Analysis

- The system demonstrated high responsiveness and accurate flame detection.
- The use of a servo-controlled nozzle ensured that water was sprayed directly onto the flame.
- No false triggering was observed under normal light conditions.
- The system worked efficiently within its designed range and voltage limits.

ADVANTAGES, LIMITATIONS AND APPLICATIONS

1. Advantages:

1. Automatic Operation: Detects and extinguishes fire without human intervention, reducing response time.
2. Low Cost: Uses affordable components like Arduino Nano, flame sensor, and servo motor.
3. Quick Response:The flame sensor reacts within seconds of fire detection.
4. Compact and Portable:The setup is small and can easily be installed in various locations.
5. Energy Efficient: Operates only when a flame is detected, conserving power.
6. Safe and Reliable: Minimizes risk by automatically controlling fires at the initial stage.
7. Customizable: Can be expanded with additional sensors or IoT connectivity for enhanced safety.

2. Limitations:

1. Limited Range: The flame sensor can detect fire only within a short distance (60–80 cm).
2. Water Dependency: The system only uses water as an extinguishing agent — not suitable for electrical or chemical fires.
3. Single Direction Operation: Works effectively only in the sensor's line of sight; cannot cover wide areas without multiple sensors.
4. No Real-Time Alerts: The prototype does not include alarm or notification systems.
5. Power Supply Requirement: Needs a stable DC supply; not suitable for areas without electricity backup.

3. Applications:

1. Homes and Kitchens: To detect and control small accidental fires automatically.
2. Laboratories: Useful for preventing fire hazards in electronics and chemical labs.
3. Workshops and Garages: Helps reduce risks from tool sparks or fuel-based fires.
4. Offices and Small Businesses: Provides safety in rooms with computers, wiring, and electrical appliances.
5. Warehouses or Storage Areas: Can protect stored materials by automatically suppressing fire at early stages.
6. Educational and Research Projects: Serves as a learning project for automation, robotics, and safety systems.

FUTURE SCOPE

- IoT Integration: The system can be connected to Wi-Fi or GSM to send real-time alerts (SMS or app notifications) to the user or fire department when fire is detected.

- AI-Based Flame Detection: Use a camera and machine learning to identify the type and size of fire more accurately than a basic flame sensor.

- Automatic Refill System: Add a mechanism to automatically refill the water tank when the level goes below a certain limit.

- Multi-Agent Coverage: Employ multiple servo motors or rotating nozzles to cover a wider area and target the fire precisely.

- Temperature-Based Control: Combine the flame sensor with a temperature sensor to confirm fire presence and avoid false triggers.

- Dual Extinguishing Media: Integrate CO_2 or dry chemical extinguishers alongside water for different types of fires (like electrical fires).

- Voice and Alarm Alerts: Add a buzzer or voice module that gives immediate warnings to nearby people before activating.

- Solar-Powered Operation: Use solar panels to power the system for use in remote or outdoor areas.

- Smart Home Integration: Connect it to smart home systems like Alexa or Google Home for monitoring and control.

- 360° Rotating Camera Module: Attach a small camera that rotates with the servo to record or livestream fire incidents for safety analysis.

CONCLUSION

The Automatic Fire Extinguisher System demonstrates an effective approach to fire detection and suppression using simple electronic components and automation principles. The system successfully identifies fire through a flame sensor and immediately activates a servo motor-controlled sprayer to extinguish the flame, minimizing human involvement and response delay.

This project highlights how embedded systems can play a crucial role in enhancing safety and preventing property damage. By integrating affordable hardware such as the Arduino Nano, servo motor, and flame sensor, the prototype achieves fast, accurate, and reliable performance within a small range. The results prove that the system is highly responsive and efficient for small-scale fire control applications like homes, laboratories, and offices.

Although the prototype has certain limitations — such as restricted detection range and single extinguishing medium — it provides a strong foundation for future enhancements. By incorporating multiple sensors, wireless communication, or IoT-based alert systems, this design can evolve into a more advanced, real-time fire management solution.

Overall, the project successfully fulfills its objective of developing a low-cost, automated fire prevention system, demonstrating both the practicality and potential of automation in modern safety systems.