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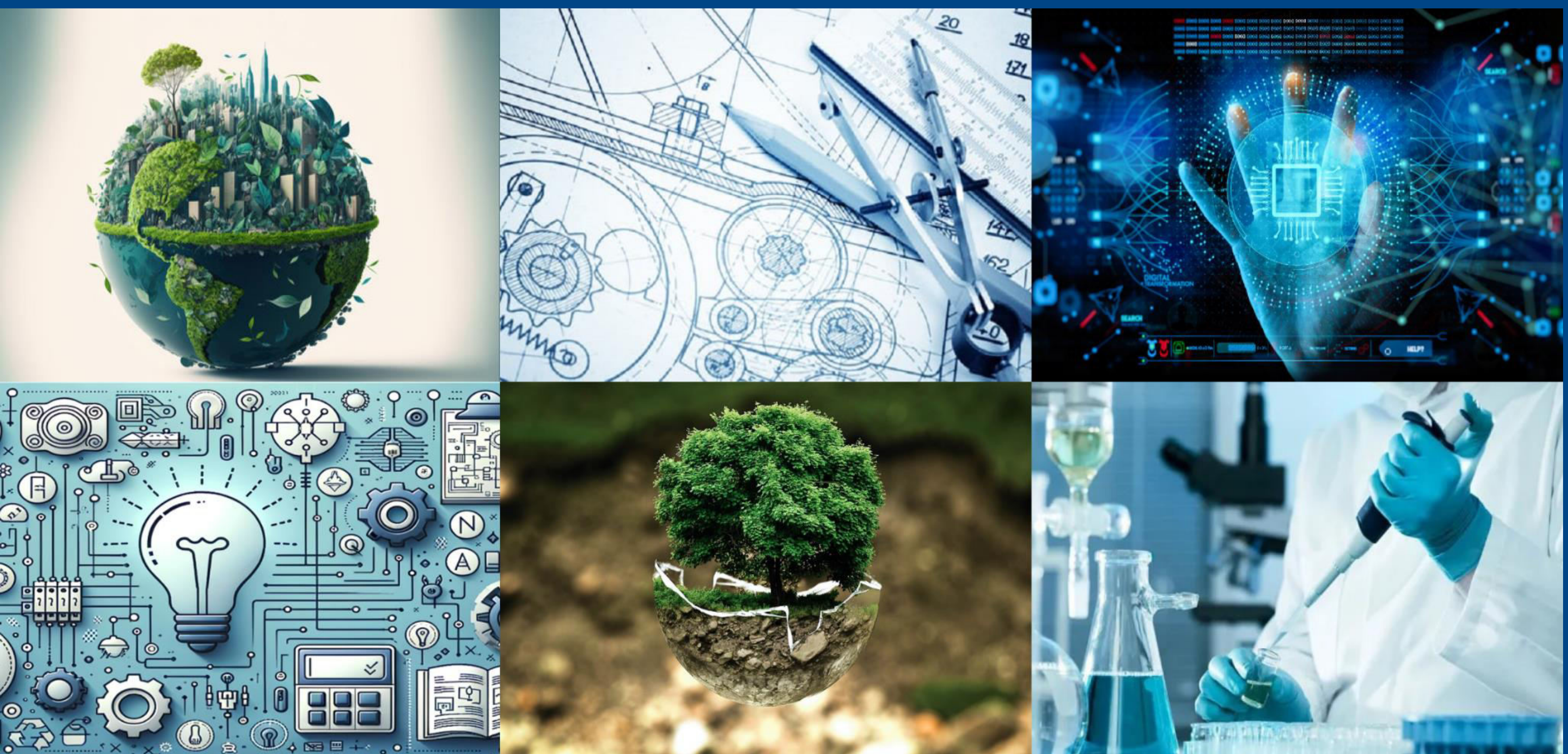

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Design and Implementation of an Automated Fire Detection and Targeted Suppression System for Large Public Spaces

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ABSTRACT— This project presents an AI-based automated fire detection and targeted suppression system for large public spaces like railway stations, malls, and airports. A custom-trained AI model detects fire and smoke in real time using CCTV feeds, with the system pinpointing the threat's exact location. Future development includes a 360-degree motorized nozzle controlled by a microcontroller to aim a high-pressure water jet directly at the fire. This targeted method minimizes water use and damage, offering a cost-effective, scalable, and efficient fire response. Currently, the AI detection system is complete, with ongoing work on integrating the targeting and suppression mechanisms.

KEYWORDS- AI fire detection, targeted suppression, high-pressure jet, CCTV integration, microcontroller control, real-time response, modular design, public safety, efficient water use, scalable system.

I. INTRODUCTION

The threat of fire in public spaces such as railway stations and malls can lead to catastrophic consequences if not addressed quickly. Current systems primarily rely on smoke detectors or sprinkler systems that may not be sufficient for rapid and targeted suppression, especially in large and crowded environments. This project proposes a novel solution that integrates fire detection with precise water jet targeting, using computer vision and AI to autonomously identify and extinguish fire sources. This system will be mounted on the ceiling and capable of 360-degree rotation, allowing it to detect and address fires from any angle.

Traditional fire suppression systems are limited in their ability to respond quickly and precisely to fires, especially in large, open spaces. Smoke alarms and sprinklers activate based on predefined thresholds, which may delay detection and response, resulting in unnecessary water damage and potentially insufficient fire containment. Our project aims to develop an automated, AI-driven fire detection and suppression system that can rapidly locate a fire and direct a high-pressure water jet to the precise location of the threat, minimizing collateral damage and enhancing fire safety in public spaces.

II. RELATED WORK

The design and development of an automated fire-detection and suppression system involves contributions from various fields, including computer vision, AI, and mechatronics. Previous research in fire detection using machine learning and image processing has provided a foundation for real-time detection in complex environments. Here, we review key research studies that have contributed to this field, focusing on fire detection techniques, suppression strategies, and limitations in existing systems.

III.METHODOLOGY

The project is divided into two main stages:

Stage 1: Fire Detection System

1. Data Collection: Gather synthetic and real datasets containing images and videos of fire and smoke for training the detection model.
2. Model Development: Train a convolutional neural network (CNN) or another suitable AI model to recognize fire and smoke patterns from CCTV footage in real-time.
3. Implementation on Laptop: Deploy the trained model on a Laptop, connected to the CCTV camera via LAN for processing live video feeds.
4. Testing and Validation: Evaluate the system's accuracy and speed in detecting fire or smoke under different lighting conditions and environmental variables.

Stage 2: Water Jet Targeting System

Mechanical Design: Create a rotational system that enables the water jet nozzle to move 360 degrees, ensuring full area coverage.

Microcontroller Selection and Integration: Decide between Arduino, Teensy, or ESP32 microcontrollers for controlling motor movements based on coordinates received from the detection system.

High-Pressure Water Jet Development: Design or source a water jet capable of accurately targeting and extinguishing fire within a specified radius.

System Integration: Combine the detection and targeting systems to create a cohesive, autonomous fire suppression unit.

IV. PROJECT FLOW CHART

Flowchart for the Stage 1 fire detection process:

1.Start
Camera Feeds Live Video to Laptop
The CCTV camera streams continuous video to the Laptop, where the AI model is deployed

2. Image Processing and Pre-Processing
Frames from the video are pre-processed, which may involve resizing, filtering, or enhancing the images to improve detection accuracy.

3. Fire Detection Model Processing
Each frame is analyzed by the AI model for signs of fire or smoke. If fire or smoke is detected, the model calculates the location coordinates.

4. Detection Output
If fire/smoke is detected:
The coordinates of the fire are sent to the microcontroller system for the next stage (targeting).
If no fire/smoke is detected:
The system continues monitoring.
End (Continuous Monitoring)

V. CONCLUSION

This project demonstrated the design and implementation of an automated fire detection and suppression system, with a particular focus on public safety in high-risk environments such as railway stations and malls. Using a CCTV camera for detection, combined with an AI model, enables accurate and efficient identification of fire and smoke.The rotating mechanism and high-pressure water jet ensure prompt and targeted suppression, minimizing potential damage and enhancing safety.

The system provides a cost-effective alternative to traditional fire suppression systems, with the advantage of precise

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targeting and real-time response. Although further testing and refinement are required to ensure reliability, this projecttablishes a strong foundation for integrating AI-based detection with mechanical suppression in public spaces

In the future, integrating additional sensors, such as thermal imaging, and optimizing the system for larger environments could further enhance its effectiveness. Additionally, upgrading to a more powerful single-board computer could improve response time, especially in high-resolution scenarios. This project represents a significant step towards automated fire management solutions, ensuring public safety and operational efficiency in large indoor spaces.

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