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Next-Gen Fire Safety AI-Powered Automated Detection and Suppression Framework

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***Abstract*— Fire suppression system based on AI, which aims to become a faster and more efficient tool than traditional sprinklers. Traditional fire suppression systems designed for commercial facilities, eliminate fires by flooding an entire area with water. The AI-based fire suppression is based on cameras, sensors, and Internet of Things (IoT) technology to provide faster identification of a fire event, with real-time data sharing to only impact the area in distress, whether that is a classroom, office, etc. This technology saves water to minimize overall costs associated with fire suppression because flooding an area creates water damage with significant cost involved to repair. Generally the AI-based fire suppression system is a faster and a more sustainable fire safety solution that can also be implemented into malls, hotels, hospitals, and office buildings.**

***Index Terms*—AI-Powered, Automated Detection, Fire Safety, IoT, Suppression Framework.**

I. Introduction

Traditional sprinklers are pretty outdated technology. They just dump water everywhere, creating a ton of water damage and unnecessary water use. The idea being expressed has to do with how all these new smart technologies (sensors, IoT, etc.) should create much more intelligent fire-fighting systems that can specify a single location of a fire, and attack it directly, which is much more effective and obviously less damaging. The tool calculates how much time is a reasonable amount of safe time for people to escape from a fire. It's particularly well-suited to complex buildings with extensive open areas, such as an atrium with a complex roof. The tool also has a manageable amount of practical and easy-to-understand advice for use in fire safety planning.

By integrating vision-based monitoring, environmental sensing, and real-time data analysis, the system directs suppression only where it is required, minimizing collateral damage and conserving resources.This paper examines the drawbacks of conventional fire control approaches, describes the essential components of the proposed solution, and demonstrates how such a system offers a more efficient, sustainable, and reliable method of protecting both people and infrastructure.

II. Literature survey

Fire spread after flashover poses serious risks, especially in unmanned ships facing crew shortages. Author presents a novel Autonomous Fire Detection and Suppression System (AFDSS) tailored for autonomous ships. The system combines RGB, IR, and UV sensors to minimize false alarms and enhance detection accuracy. A reinforcement learning algorithm optimizes water spray patterns under varying sea conditions. Experiments confirm the system's effectiveness in ensuring fire safety during simulated maritime scenarios [1]. A real-time computer vision-based fire detection and suppression system is proposed to enhance fire safety. The multilayered algorithm uses color clues and three filtration stages: Centroid, Histogram, and Variance Analysis. It achieves 95.26% overall accuracy with high true positive (91.61%) and true negative (98.91%) rates. The

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system outperforms existing methods with notable gains in accuracy (7.95%) and precision (9.43%). Integrated with an Arduino-based suppression unit, it ensures autonomous response and high reliability across diverse environments [2]. Fire detection is crucial due to its severe consequences, making early, reliable automated systems essential. This review explores the latest in fire detection, prevention, and propagation modeling using machine learning. Fourteen deep learning datasets were critically examined for quality,

imbalance, and diversity. Key research gaps include dataset imbalance, misclassification, and the need for advanced models like transfer learning and vision transformers [3]. The Intelligent Fire Engineering Tool (IFETool) is an AI-based software developed to accelerate fire safety analysis in buildings, particularly atriums. It uses a large numerical database of fire scenarios and deep learning to predict smoke visibility, temperature, and CO levels with 97% accuracy. The tool evaluates Available Safe Egress Time (ASET) based on tenability profiles. IFETool is effective for analyzing complex atrium designs with unique roof and slab features. It also offers user-friendly guidelines for practical fire safety design tasks [4].

III. TECHNOLOGY DETAILS

This intelligent fire system employs artificial intelligence as its cognitive ability to effectively and efficiently respond to fire safety. Its camera applies the artificial intelligence appropriately to detect flames, smoke or just heat signatures with amazing accuracy. This reduces false alarms. It also uses computer vision, which constantly monitors footage from a 360° camera to visually detect a fire as it occurs. All sensors, cameras, control units, and suppression mechanisms are interconnected, allowing for remote monitoring and instant communication by using IoT technology. An array of sensors including flame, smoke, temperature, and gas detectors act as a first layer of detection, continuously monitoring the environment for fire indicators beyond visual inputs. Microcontrollers based systems like the ESP32 is used as the hardware backbone for processing sensor data and autonomously controlling suppression units. Motor drivers and relay modules further used for actuation of suppression systems, such as activating pumps or CO_2 dispensers in targeted areas. The use of cloud storage and analytics enables the system to log activities, facilitate predictive maintenance, and improve AI model accuracy through continuous learning. Wireless communication protocols like Wi-Fi, GSM, or MQTT provide reliable connectivity for real-time alerts and system updates, ensuring swift responses during emergencies. Finally, an optional mobile app or dashboard serves as an intuitive user interface, offering real-time system monitoring, alerts, and manual control options, empowering users with both oversight and immediate action capabilities.

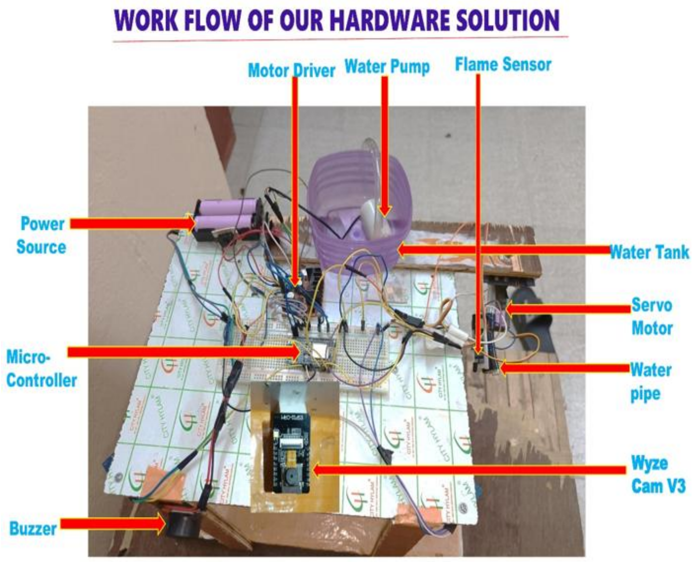

Fig. 1. illustrates the hardware workflow of the Smart Fire Detection and Suppression System

IV. BLOCK DIAGRAM AND WORK FLOW

To begin, the process starts with a flame sensor that is constantly monitoring for fire. Upon detection of fire, it sends a signal that automatically powers on a smart AI camera. The smart AI camera records the area, and then uses computer vision to review the recording and determine if fire is present. Once the system calculates the precise coordinates and distance of the fire, it transmits that information to a central database. A motor that has the capability of rotating 360° reads the location of the fire and positions the water pipe to the fire. That placed it in the correct position, where a pump engages that pulls water and sprays directly onto the fire. The system has a buzzer also, to warn people nearby. Essentially, this smart, all-in-one fire response system utilizes AI and IoT to function over a variety of scales, and to operate with very little complexity, as it is designed to be efficient. Additional elements like a buzzer alert nearby users, and a power source keeps the system operational. This figure effectively demonstrates a modular, scalable, and intelligent fire response solution that combines AI, IoT, and embedded systems for high-efficiency real-time performance.

Methodology: Stepwise Process Flow of Smart Fire Detection and Suppression System

The indigenous Smart Fire Detection and Suppression model follow a six-step to ensure accurate and self driven fire management.

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Step 1 This step involves sensor-based initial fire detection, where the model continuously monitors the temperature ,gas level from flame, smoke, infrared (IR), and temperature sensors. A fire is detected when the temperature level cross the predefined threshold temperature level by the detection of flame or smoke sensors and it triggers the next stage of the process.

Step 2 After confirmation of a fire threat by the sensors, an AI Based 360° rotating camera is activated and directed toward the suspected zone. This camera captures real-time video and uses advanced computer vision algorithms to confirm the presence of fire, as well as the extract coordinates points to estimate the distance of the fire source from the system.

Step 3 Then real-time data transmission process is initiated. The spatial data including coordinates points and distance obtained from the AI module is transmitted to the Firebase Real time Database, by using instantaneous cloud-based communication application. This ensures that all connected components are updated simultaneously and without delay.

Step 4 Then A servo motor-controlled hose alignment mechanism is activated. A water hose system mounted on a servo motor with 360° rotation capability reads the fire coordinates continuously from the Firebase database. After receiving updated data, the motor precisely aligns the hose in the direction of the fire source to prepare for suppression.

Step 5 This is the targeted fire suppression activation stage. Once the hose is correctly leaning toward the fire, the system automatically triggers the suppression mechanism typically a high-pressure water spray. This allows for immediate and focused action, extinguishing the fire with minimal delay and maximum efficiency.

Step 6 highlights the system's attributes and advantages. The entire process is fully automated and AI-enhanced, allowing for accurate detection and precise targeting. With cloud-based control via Firebase, the system is scalable, modular, and highly efficient, making it adaptable to a wide range of industrial, commercial, and remote applications with minimal manual intervention.

V. FLOW CHART

The figure 2 illustrates the logical operational sequence of the Smart Fire Detection and Suppression System, highlighting how it autonomously manages fire events from detection to extinguishment. The Smart Fire Detection and Suppression System fully automates the entire fire process, from detection through suppression and everything in between. In default standby mode, the system continuously monitors the environment. Sensors detect the fire and trigger the activation of a camera providing a 360-degree view of the area's context and support the AI computer vision system that confirms the presence of fire and precisely locates where the fire is situated.On the basis of this confirmed evaluation, the motorized pump is activated to

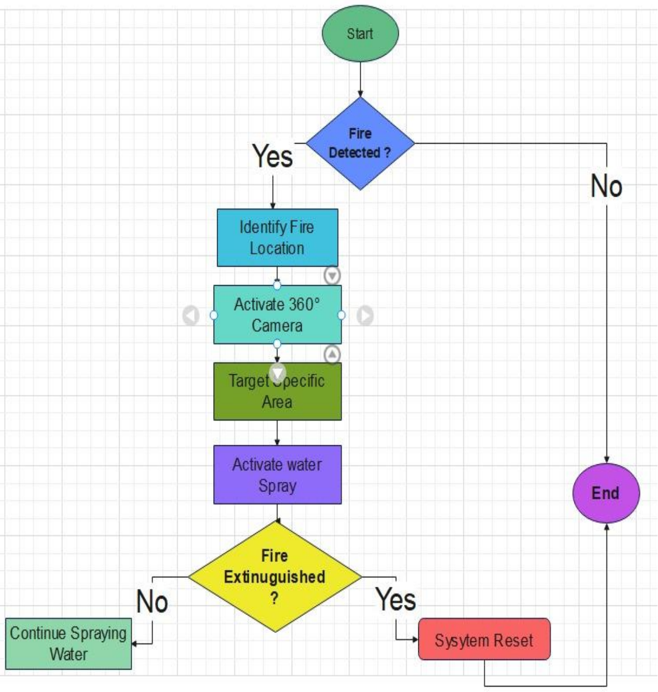

Fig. 2. illustrates the logical operational sequence of the Smart Fire Detection and Suppression System

accurately aim the hose and begins suppression of the fire. Once suppression begins, the system will continue to monitor the fire event for emergence and only stop the water spray once confirmed that the fire is completely out. The system then resets itself for the next potential fire event. This is all able to happen in an automated manner with little human involvement, giving the ability to act quickly and accurately which increases overall safety.

VI. OUTCOMES

The assembled prototype of the Smart Fire Detection and Suppression System is illustrated in Figure 3. The system is situated on a wooden frame, which serves to house the

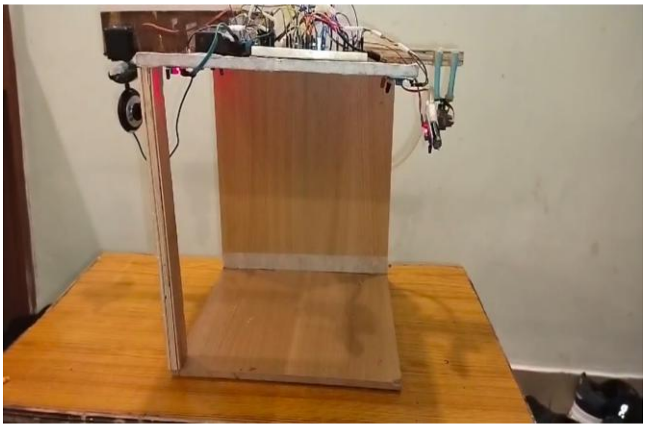

Fig. 3. showcases the practical outcome of the Smart Fire Detection and Suppression System prototype.

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framework and primary components: a 360° AI camera module, flame sensors, and a water dispensing mechanism. The main control system resides on the frame's elevated platform, which is where the microcontroller (i.e. an ESP32), all motor driver and relay modules and power source connect to appropriately govern detection and suppression functions. A key element is the configuration of servo motors on the frame, which permit the entire product to rotate to reliably position and aim the water jet to the right spot for any detected fire.
The hardware of the system, which consists of a piping system connected to a water reservoir, works together with an automated process flow that begins with real-time detection by sensors, localization with cameras, and ends with extinguishment using a servo.

The integral placement of sensors and actuators provides and achievable 360-degree coverage zone, which is especially useful for applications found in industrial spaces, or on autonomous ships. The system can function fully automated and immediately responds to a fire without human interaction. The figure 4 shows all type of alert of the system.

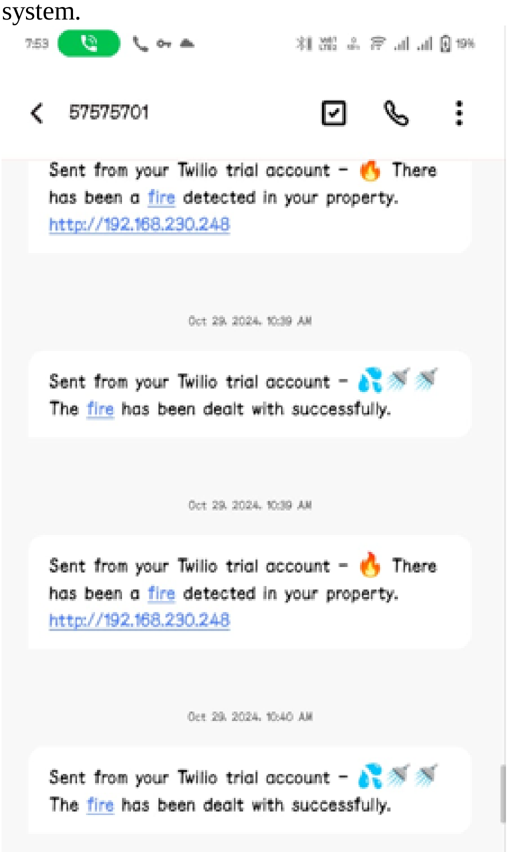

Fig. 4. shows all type of alert of the system.

All in all, this prototype is a viable demonstration of an effective AI and IoT powered fire suppression system, proving its potential for real-world smart safety systems.

VII. Conclusion

The Smart Fire Detection and Suppression System give you an idea about how current technologies can be combined to improve fire safety. It uses AI, IoT, computer vision, and embedded systems to create an indigenous intelligent and automated solution. The flame, smoke, and temperature sensors are used to detect the fire. Along with these, a 360° rotating AI-based camera detects the exact fire location. A water spraying unit then targets the affected area quickly which is control by servo motor. Real-time data based is managed through Firebase. The communication between all parts of the model happens using Firebase and it allows faster response during fire incidents. A working hardware prototype model has been developed. The design is indigenous and can be scaled for larger use. The model can be applied in different areas such as autonomous ships, smart homes, and industrial environments. In conclusion, this solution provides a reliable and efficient way of managing fire automatically. It reduces the need for human involvement and increases both safety and response speed.

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