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Integrated Fire Detection System using ML and IOT

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Abstract: An integrated fire detection system that combines smoke, thermal, and image analysis using machine learning can provide real-time fire detection and reduce false alarms, thereby enhancing safety. Traditional single-sensor fire detection systems that rely on smoke or heat often result in false alarms or delays. The proposed multi-model system involves combining smoke, thermal, and YOLO v8 image detection technologies. However, challenges such as data privacy, cost, and maintenance need to be addressed. Nevertheless, this advanced fire detection system has the potential to significantly improve fire protection.

I. INTRODUCTION

Traditional fire detection systems have been the go-to solution for building safety for a long time. These systems rely on reliable technologies like smoke and heat detectors to detect potential fire hazards. Smoke detectors come in two main types: photoelectric and ionization. Photoelectric detectors use a light beam to sense disruptions caused by smoke particles, while ionization detectors rely on electrical currents that get disrupted by smoke's presence. Both types trigger a loud alarm upon detection to warn occupants. Heat detectors, on the other hand, contain a heat-sensitive element that triggers an alarm when there's a rapid or extreme temperature increase, which can signify a fire even before smoke develops. While these traditional systems are effective, they do have their limitations. Buildings are often divided into zones with multiple detectors wired together. When one detector gets activated, it triggers the entire zone's alarm, which is great for large spaces but lacks precision. Evacuating a whole floor for a fire in a single room is not ideal! Additionally, these systems can't pinpoint the exact location of the fire, making it harder for firefighters to locate the source quickly. Despite these drawbacks, traditional fire detection systems remain popular because they are simple and affordable compared to newer technologies. They offer a proven layer of protection, even with their limitations.

Fire detection is crucial for protecting lives and property from the destructive consequences of fires. Smoke detectors, which are the most commonly used, act as the first line of defense. These devices use photoelectric or ionization technology to detect smoke particles and trigger a loud alarm to alert occupants. Heat detectors, another prevalent technology, work differently. They monitor for rapid or extreme temperature increases, which may signal the presence of a fire even before smoke accumulates. Fire detection has gone beyond traditional sensors, with modern systems using video cameras and complex algorithms to visually identify flames. This multi-pronged approach, with smoke, heat, and visual detection, significantly increases a system's ability to raise an alarm in the early stages of a fire. Early detection is essential, as it provides ample time for occupants to evacuate safely and emergency services to be alerted. By implementing a comprehensive fire detection system, you significantly increase your chances of preventing a fire's harm. Fire detection is on the brink of a high-tech upgrade with YOLOv8, a cutting-edge image recognition system. Unlike traditional detectors that rely on heat or smoke signatures, YOLOv8 uses cameras and artificial intelligence to detect fires. By training on a massive dataset of images containing flames and smoke, YOLOv8 is capable of recognizing these visual cues in real-time video streams. This means that fire detection can be faster and more accurate, especially in situations where traditional methods may not work. Imagine identifying a small fire with just a wisp of smoke before it becomes a major blaze. The advantages are clear: faster response times can make all the difference between a minor scare and a catastrophic fire. YOLOv8 can cover wider areas with ease, making it ideal for safeguarding larger spaces or multiple buildings. Additionally, this technology can be integrated with automated systems, triggering alarms or deploying fire suppression measures the moment a fire is detected - a crucial advantage in situations where every second counts. However, to make the most of YOLOv8, a high-quality dataset is necessary for effective training, and some technical expertise is required for setup and implementation. But with these considerations taken care of, YOLOv8 offers a glimpse into the future of fire detection, providing faster, more intelligent protection for our homes and businesses.

II. LITERATURE SURVEY

[1] This work presents YOLO-SF, a revolutionary fire detection algorithm that addresses the low accuracy and missed detections of existing approaches.

By combining object identification and instance segmentation, YOLO-SF significantly increases recall and precision. In order to do this, the researchers installed a segmentation detection head to capture finer fire characteristics and developed a customized fire segmentation dataset for training. They also used a Convolutional Block Attention Module (CBAM) to direct the network's attention toward critical fire data, and included a lightweight and effective MobileViTv2 module for feature extraction. To address the problem of imprecise fire boundary detection, they employ Varifocal Loss. Precision, recall, and mAP are three accuracy metrics where YOLO-SF outperforms current techniques while preserving real-time speed (55.64 FPS). This new algorithm offers both strong generalization capabilities and robustness, making it a promising solution for real-world fire detection.

[2] Several YOLO object detection models (YOLOv5-YOLOv8, YOLO-NAS) are evaluated in this study for early smoke and wildfire detection. During training, the models prioritize recall, or locating all smoke. They are evaluated on public and real-world datasets. While distant smoke, dim lighting, and sporadic false positives are issues that all models face, some perform better than others. For example, YOLOv5, YOLOv7, and YOLOv8 provide balanced performance, YOLO-NAS prioritizes finding all smoke (even with some false positives), and YOLOv6 offers a good balance with a minor recall trade-off. This study emphasizes that the optimal model selection is contingent upon the requirements of the application (recall vs. accuracy), which ultimately helps in determining the optimal YOLO model for enhanced wildfire detection systems.

[3] This paper uses camera networks for early wildfire detection. It suggests a two-pronged strategy: an ideal camera placement plan to optimize coverage within financial restrictions, and a lightweight smoke detection program for on-camera analysis employing image processing. Real-world testing has proven the smoke detection and placement techniques, which makes this a potentially useful technology for faster wildfire response times and less damage.

[4] This paper addresses the sensitivity of Convolutional Neural Networks (CNNs) to the irregular shapes and sizes of fire, which is one of CNNs' limitations in fire detection. The suggested approach takes care of this by employing a self-attention mechanism to incorporate temporal information with spatial data. This makes the network more resilient to fluctuations in firing by allowing it to concentrate on the relationships between features in an image sequence rather than merely their location. Using the integrated spatiotemporal data, the system is executed in two stages: first, it proposes fire regions; next, it classifies such regions as fire or not. Accurate fire detection is much improved by this strategy, especially for tiny fires that are detected early on. The system uses transfer learning to overcome the problem of limited fire data, requiring only one tagged image per video sequence for training.

[5] Although early wildfire detection is essential, conventional techniques like satellites have drawbacks. Because of their quick deployment, low flying altitude, and three-dimensional mobility, this study suggests that drones (UAVs) can be an invaluable tool for gathering important information in the early phases of a fire. Unfortunately, advancement is hampered by inadequate training data for drone-based fire detection systems. In order to tackle this, scientists present an exclusive dataset gathered using a UAV. This multi-modal dataset includes side-by-side RGB and thermal image captures. In addition, each image has human-labelled data ("fire" or "no fire") and contextual data (weather, burn plans, etc.). This extensive dataset provides a basis for creating sophisticated deep learning-based fire detection and modelling methods, opening the door to more precise and timely.

[6] The topic of this essay is wildfire smoke detection, an essential stage in reducing wildfire damage. Current techniques frequently encounter false positives and necessitate intricate feature extraction. The authors suggest a unique 3D parallel fully convolutional neural network that approaches smoke detection as a segmentation problem in order to overcome this. This network efficiently separates smoke from natural sights in a variety of situations by segmenting smoke regions from video sequences. The system, which was trained on a dataset of more than 90 movies, shows excellent accuracy and speed in identifying smoke in a variety of scenarios, which could speed up the response time to wildfires.

[7] In order to address the growing worry about fire mishaps, this article suggests an IoT-based real-time fire detection system. The system makes use of a number of sensors to gather information on smoke, temperature, humidity, and even building occupancy. A dashboard that is easy to use is then used to remotely monitor this data. Crucially, in the event that any reading surpasses safety standards, the system initiates multi-level alarms (light, buzzer, SMS). Its potential to count people, which helps with evacuations, is a special feature. The study ends with encouraging test findings and suggests further developments utilizing AI and camera integration for improved fire detection in the future.

[8] This study examines developments in fire detection with a focus on fire safety. Although deep learning in computer vision presents a promising alternative, traditional methods have drawbacks. The study examines current deep learning fire detection methods and outlines YOLOv5's benefits. The experiment to develop a prototype fire detection system utilizing YOLOv5 and PyQT5 is then described. The experiment shows that YOLOv5 obtains higher accuracy in detecting fires.

[9] Accurate fire detection in infrared photographs is a persistent difficulty faced by building owners and firefighters.

Despite their importance, these photos frequently have poor resolution and insufficient information, which causes false alarms and missed fires. In order to address these constraints, a novel deep learning technique is put forth in this study. The technique includes two major modifications: it integrates CSP_ResNet and SPP networks to efficiently extract even minute fire details from the full image, and it swaps out pooling layers with convolutional layers to preserve features. The suggested model achieves a substantially reduced false alarm rate and a stunning 94.35% fire detection accuracy (mAP) using a custom dataset – a 6.06% improvement over existing methods. Experiments verify considerable improvements. The potential for this creative strategy to greatly improve fire safety through more accurate fire detection in infrared imaging.

[10] This research proposes a novel approach that combines the enhancement of fuzzy details using Local Contrast Normalization (LCN) and the extraction of valuable pedestrian features from images using Histogram of Oriented Gradients (HOG) to improve pedestrian detection in foggy conditions. When coupled, these techniques provide efficient pedestrian identification, even in difficult misty situations when they are ineffective for other purposes.

III. PROPOSED SYSTEM

The proposed integrated fire detection system aims to elevate fire protection to a new level by combining the strengths of multiple sensing technologies and advanced image processing algorithms. This synergistic approach addresses the limitations of individual detection methods and enhances overall system accuracy and reliability.

By integrating all three detection modalities, the proposed system overcomes the shortcomings of individual methods and provides a more comprehensive and reliable fire detection solution. Smoke detection alerts the system to the presence of combustion, while thermal detection identifies the rapid temperature increase associated with fire. Additionally, YOLO v8 image detection provides visual confirmation of fire-related objects, enhancing the system's confidence level and reducing false alarms.

The proposed system's architecture involves a tiered approach. Smoke and thermal detectors are deployed throughout the protected area, continuously monitoring for smoke and temperature changes. Video surveillance cameras capture real-time footage of the environment, which is fed into the YOLO v8 object detection algorithm.

When a smoke detector or thermal sensor detects a potential fire hazard, it sends an alert to the central control unit. Simultaneously, the YOLO v8 algorithm analyzes the video feed, searching for fire-related objects. If the central control unit receives alerts from multiple sources or if YOLO v8 confirms the presence of fire, the system triggers an alarm, activating evacuation protocols and notifying emergency responders.

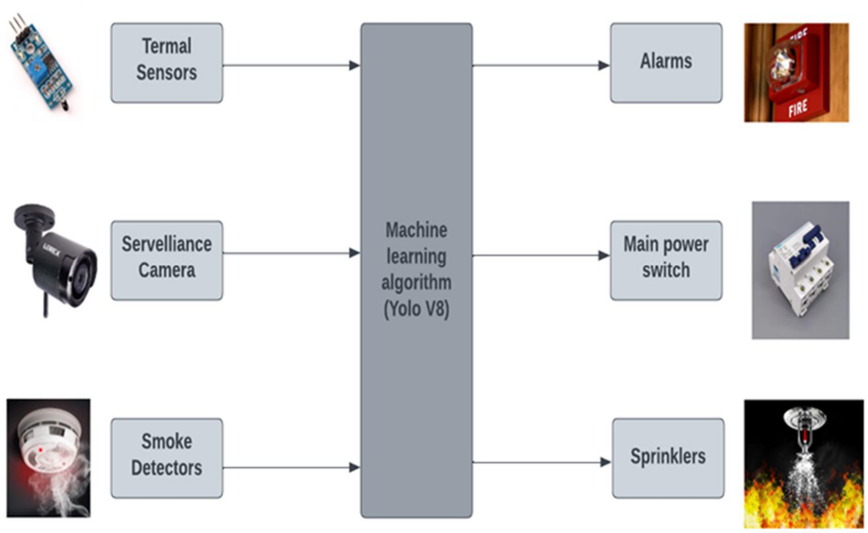

Fig 1: Block Diagram

The fire detection system is composed of several components that work hand-in-hand to accurately identify fire. These components include thermal sensors, smoke detectors, a machine learning algorithm, surveillance camera, main power switch, and fire alarm. Thermal sensors are designed to detect heat radiating from objects and can detect fire even in low-light or smoky conditions.

Smoke detectors, on the other hand, sense smoke particles in the air, which is a clear sign of fire. The machine learning algorithm is the core of the system, and it's likely based on You Only Look Once (Yolov8) that has been trained on a vast dataset of images and videos containing fire and non-fire scenarios. The Yolov8 can distinguish fire from other elements in an image or video frame. The surveillance camera captures visual data of the environment, which the machine learning algorithm uses to identify fire based on visual features like flames or smoke. The main power switch allows the system to be turned on or off. Lastly, when the system detects fire, it triggers an alarm to notify people in the vicinity. Overall, this machine learning system offers a comprehensive approach to fire detection by combining thermal and smoke sensing with visual inspection through a camera. It has the potential to improve fire detection accuracy and speed by utilizing machine learning algorithms.

IV. CONCLUSIONS

Smoke detectors and thermal sensors are frequently used in traditional fire detection systems, yet they can cause false alarms and fail to detect fires in their early stages.

To address these limitations, Integrated Fire Detection System that combines smoke detection, thermal detection, and YOLO v8 image detection is needed.

V. FUTURE SCOPE

Integrated fire detection systems utilize multiple layers of detection to enhance accuracy and reliability. This includes smoke detection, thermal detection, and YOLO v8 image detection, resulting in real-time fire hazard detection and notification. The system integrates data streams into a centralized monitoring system, allowing for data acquisition, processing, analysis, and alarm triggering. It also provides real-time monitoring of system status and maintenance procedures. Integrated fire detection systems offer a comprehensive approach to early fire detection, proving to be accurate and reliable in various settings.

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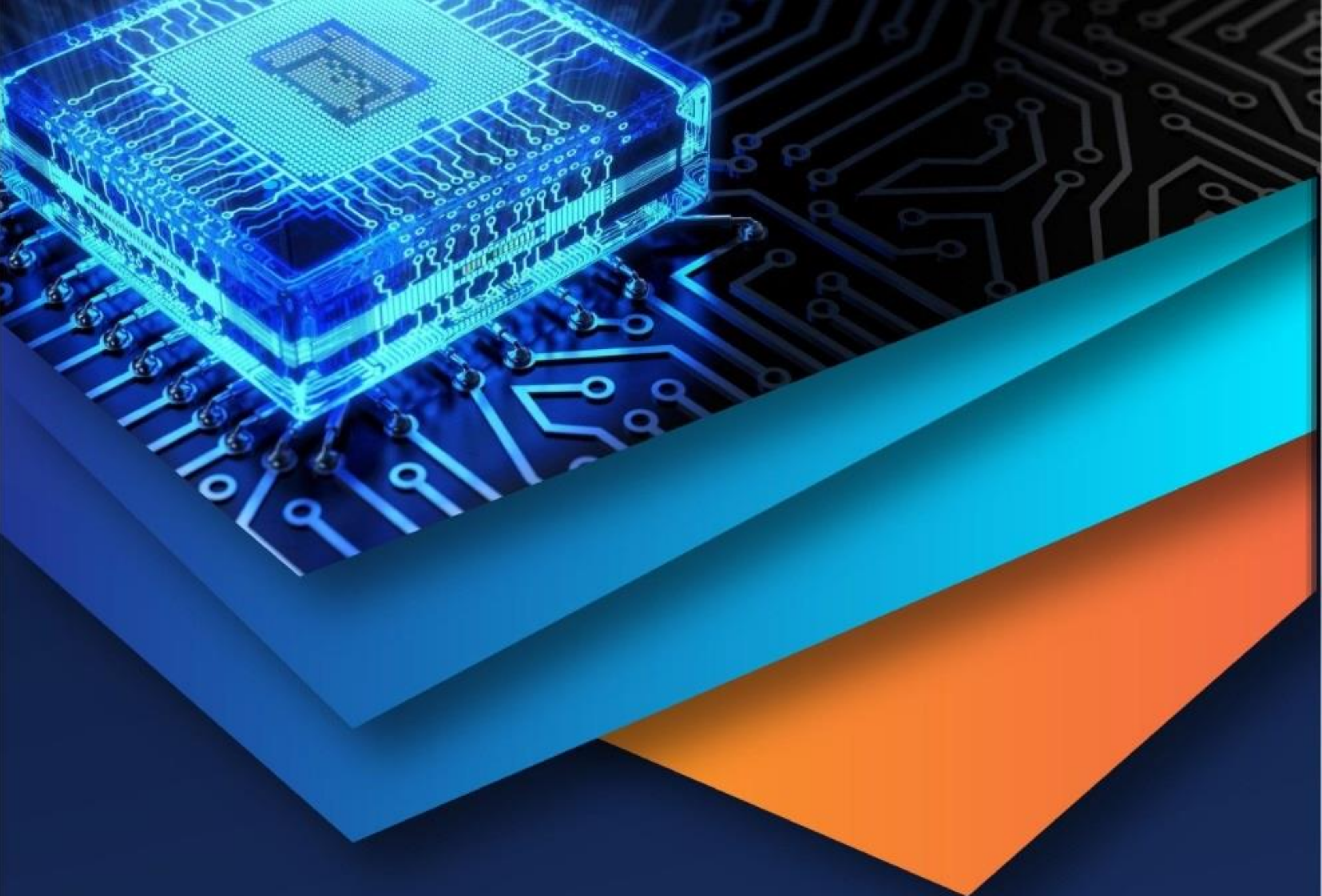

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