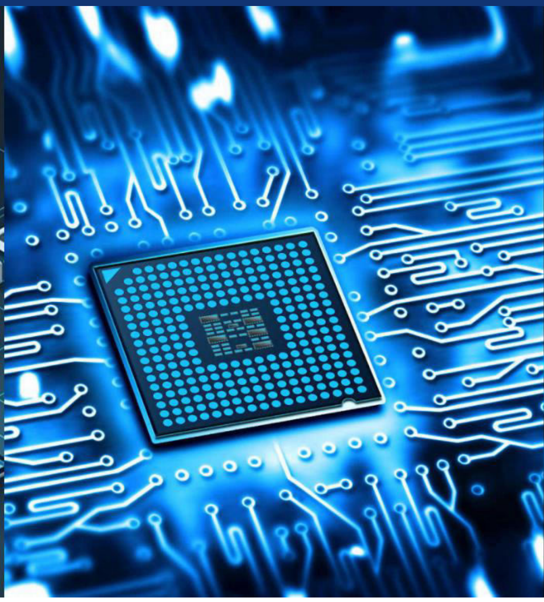
ISSN(O): 2320-9801
ISSN(P): 2320-9798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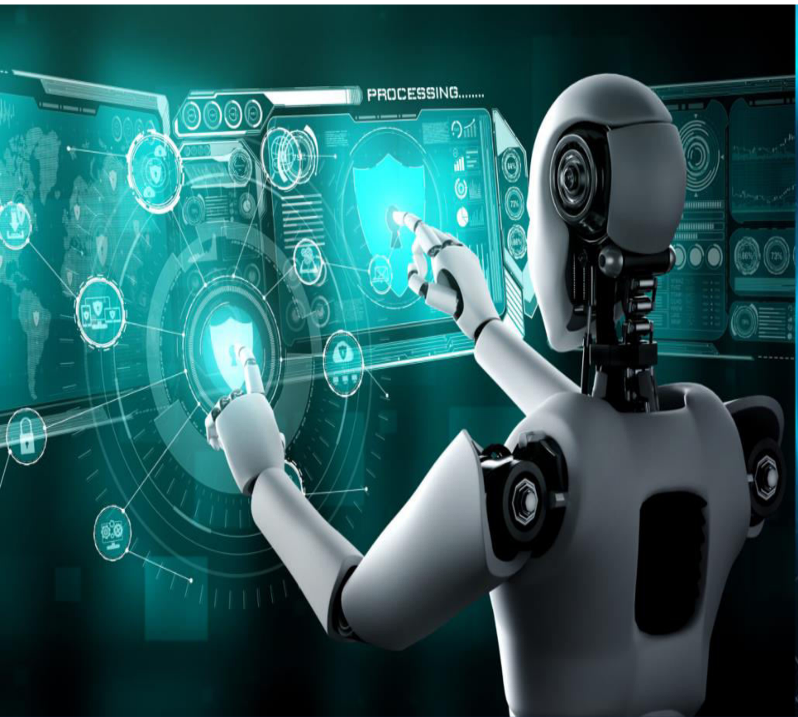

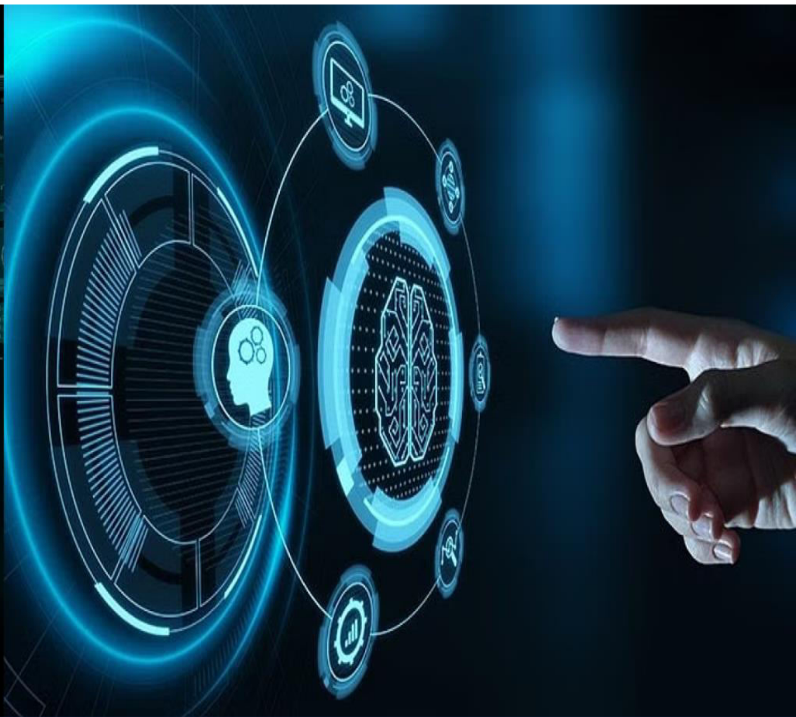

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Volume 14, Issue 4, April 2026

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International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)

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To Design AI Fire Detection and Response Platform Real Time Video Base Fire and Smoke Detection with Automated Emergency Response

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ABSTRACT: Rapid advancements in computer vision and artificial intelligence have opened new possibilities for automated industrial safety systems. This project presents AI Fire Detection and Response Platform designed to process live video feeds and detect the presence of smoke and flames at the earliest stages, triggering automated multi-channel alerts to prevent large scale disasters in industrial facilities. The system is built as a full-stack web application with a React 18 frontend and Node.js Express.js backend. The AI detection engine implements a multi-stage pipeline combining HSV colour-space fire signature analysis, temporal motion analysis, flicker pattern detection (fire oscillates at 1–15 Hz), and smoke texture detection using an ensemble voting algorithm. This multi-stage approach achieves near-zero false-positive rates while maintaining high sensitivity to real fire events. Build and validation testing confirmed 2,206 frontend modules compiling to a 600KB bundle, all API endpoints returning correct responses with sub-2ms latency, and the WebSocket server delivering real-time detection events. The system is fully operational and architecturally ready for integration with production ML models such as YOLOv8.

KEYWORDS: Fire Detection, Smoke Detection, Computer Vision, HSV Colour Analysis, Flicker Detection, Real-Time Surveillance, WebSocket, Node.js, Express.js, React, SQLite, Twilio, SMTP, Multi-Camera Monitoring, Factory Safety, Emergency Notification, AI Safety Platform.

I. INTRODUCTION

Fire and smoke incidents in industrial environments, factories, warehouses, and public buildings pose severe risks to human life, equipment, and infrastructure. According to global industrial safety reports, fire incidents account for significant loss of life and billions in property damage annually. Traditional fire detection systems rely primarily on physical smoke detectors and heat sensors that require smoke or heat to physically reach the sensor before triggering an alarm, by which time the fire may have escalated to a dangerous level. With the widespread deployment of IP surveillance cameras in industrial and commercial facilities, and rapid advances in computer vision and AI, there is a compelling opportunity to build intelligent fire detection systems that operate continuously on camera feeds to identify fire and smoke at the earliest visual stage — often minutes before a physical sensor would trigger. AI Fire Detection and Response Platform is an AI-powered fire detection and automated emergency response platform that addresses this need. The system processes live video feeds from multiple IP cameras using a multi-stage computer vision pipeline that analyses HSV colour signatures, temporal motion patterns, and fire flicker frequencies to detect fire and smoke events with high confidence and low false-positive rates.

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II. LITERATURE REVIEW

The field of automated fire detection using computer vision has been actively researched over the past decade. This chapter reviews significant works that have directly contributed to the design decisions in the AI Fire Detection and Response Platform. Muhammad Aman et al. proposed a deep learning-based fire detection framework using convolutional neural networks (CNNs) trained on large-scale annotated fire image datasets comprising over 50,000 images across diverse industrial environments. The study demonstrated detection accuracy exceeding 94% on benchmark datasets with real-time inference at 30 frames per second on embedded GPU hardware (NVIDIA Jetson Nano). The authors compared CNN-based detection against traditional threshold-based colour detection and found a 34% reduction in false positive rate with the CNN approach. The relevance to AI Fire Detection and Response Platform is the validation that colour-based analysis (which forms the first stage of our HSV pipeline) forms an effective initial detection filter when combined with temporal analysis.

III. METHODOLOGY

A. EXISTING SYSTEM

Traditional fire detection and suppression systems in industrial settings rely primarily on physical sensors mounted at fixed locations throughout a facility. The predominant sensor type; Ionisation Smoke Detectors: Use a small amount of radioactive material to ionise air in a sensing chamber. Effective for fast-flaming fires that produce small combustion particles. Susceptible to false alarms from cooking smoke and steam. Photoelectric Smoke Detectors: Use a light beam and detector. When smoke particles enter the chamber, they scatter the beam, triggering the alarm. More effective for slow-smouldering fires and less prone to kitchen false alarms.

B. DISADVANTAGE

- CCTV integration.
- Object detection models.
- Alerting System.
- Integration complexity.
- Processing latency.
- High dependency on network.

C. PROPOSED SYSTEM

The proposed AI Fire Detection and Response Platform system is a camera-based AI fire detection and automated emergency response platform that addresses all identified limitations of existing systems. The system uses existing camera infrastructure as sensors, applies a multi stage computer vision detection pipeline on the backend, and delivers immediate automated notifications via multiple channels upon detection. The detection engine implements four independent analysis stages: (1) HSV colour-space fire signature analysis that identifies orange-red fire pixel regions with high saturation and brightness; (2) temporal motion analysis on rolling frame history to detect the dynamic nature of fire; (3) flicker pattern analysis that identifies the characteristic 1–15 Hz oscillation frequency of fire brightness; and (4) smoke texture detection that identifies low-saturation, mid-brightness greyish regions consistent with smoke. An ensemble voting algorithm combines all four scores to produce a final confidence percentage.

D. ADVANTAGES

- AI-powered fire detection and response platform.
- Real-time video analysis using CCTV cameras.
- Automated alerts and emergency responses.
- Integration with existing fire suppression systems.
- Enhanced accuracy and reduced false alarms.
- Scalable solution for various environments (industrial, commercial, residential).
- Remote monitoring and management capabilities.

E. DESIGN OF THE SYSTEM

AI Fire Detection and Response Platform follows a three-tier client-server architecture: • Tier 1 – Presentation: React 18 SPA running in the browser, communicating over HTTP REST and WebSocket with the backend. • Tier 2 –

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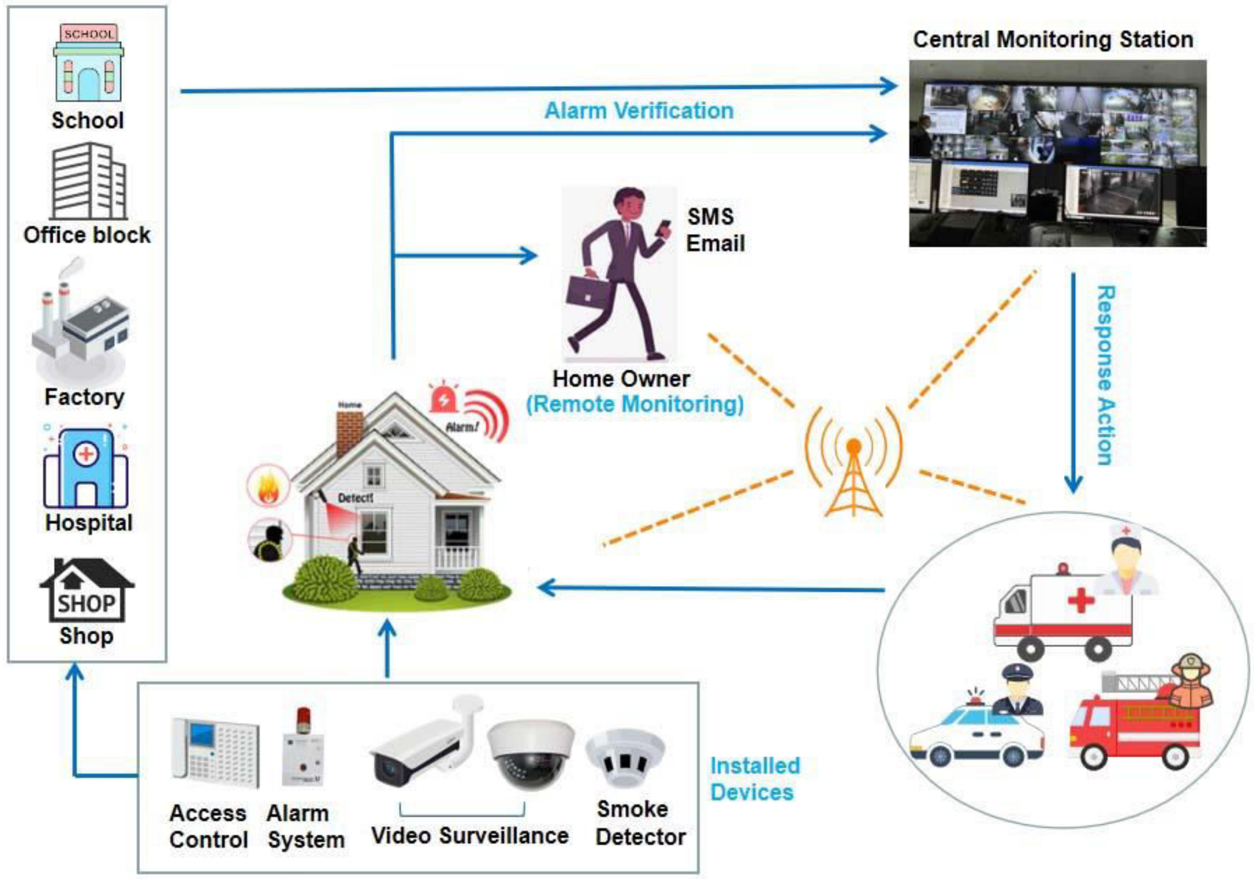
Application: Node.js Express.js server handling REST API requests, running the detection polling loop, managing WebSocket connections, and dispatching notifications. • Tier 3 – Data: SQLite database (better-sqlite3) for persistent storage of cameras, alerts, and settings; Nodemailer/SMTP and Twilio Voice for outbound notification delivery. The system exposes the following URL routes on port 5000: /api/cameras (CRUD), /api/alerts (CRUD + resolve/false-alarm), /api/settings (read/update), /api/stats (system statistics), /api/stream/:cameraId (video proxy), /api/debug/* (test utilities), and /ws (WebSocket endpoint).



The architecture diagram above illustrates the complete AI Fire Detection and Response Platform system flow. Installed devices — including Access Control panels, Alarm Systems, Video Surveillance cameras, and Smoke Detectors — feed detection data into the central server. The platform serves multiple facility types (Schools, Office Blocks, Factories, Hospitals, Shops). On fire or smoke detection, the system simultaneously notifies the facility owner/manager via SMS and Email for Remote Monitoring, forwards verified alarms to the Central Monitoring Station for Alarm Verification, and triggers a Response Action by dispatching Emergency Services including Fire Trucks, Police, and Ambulance

IV. IMPLEMENTATION

MODULES

1. LIVE DETECTION FEED MODULE (LIVEDETECTION.TSX):

The Live Detection Feed page is the primary operational monitoring interface. It displays a camera selector row at the top, a live feed viewer in the left column, and a real-time detection log in the right column. The camera selector buttons show per-camera detection state (green dot for clear, red pulsing dot for fire detected) sourced from WebSocket detection events. The detection log displays the last 12 detection events in reverse chronological order, updating in real-time via WebSocket push.

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2. CAMERA MANAGEMENT MODULE (CAMERAS.TSX):

The Cameras page provides full CRUD management for camera registrations. The add/edit form supports four camera types: LAN/IP Camera (HTTP URL), RTSP Stream (rtsp://), Local Video File (filesystem path), and USB/Webcam (HTTP stream URL). The form provides contextual URL placeholder hints that change based on the selected camera type. Camera cards display the camera name, location, type, URL, current status, and last-seen timestamp. Each card provides Enable/Disable toggle, Edit, and Delete actions. Delete requires a confirmation click to prevent accidental removal.

3. ALERT MANAGEMENT MODULE (ALERTS.TSX):

The Alerts page displays the complete detection history with dual filter controls: status filter (All / Active / Resolved / False Alarm) and type filter (All / Fire / Smoke / Both). The alert table shows: ID, detection type with icon, camera name, location, confidence bar with percentage, timestamp, status pill, and action buttons. Active alerts offer Resolve and False Alarm actions. All filter state is local to the component and does not trigger API refetch, providing instant filtering without server round trips. WebSocket alert events trigger an automatic data refetch to include new alerts in the list.

4. NOTIFICATION SERVICE (NOTIFICATIONS.TS):

The Notification Service dispatches alerts via two parallel channels. The sendEmailAlert() function creates a Nodemailer transporter from the SMTP URL setting and sends a rich HTML email containing the detection type, confidence level, camera name, location, facility name and address, detection timestamp, and emergency contact numbers. The makePhoneCall() function creates a Twilio REST client and dispatches a TwiML voice call with a bilingual (en-IN) spoken alert message to the target phone number. The main sendAlertNotifications() function dispatches all four notifications (email + fire station + ambulance + manager) simultaneously using Promise.allSettled() and logs the results to the server console.

5. DASHBOARD MODULE (DASHBOARD.TSX):

The Dashboard page provides a real-time system overview with five key metric cards: Active Cameras (with total count), Active Alerts, Today's Alerts, Total All-Time Alerts, and System Uptime. All stats are fetched from the /api/stats endpoint with a 5-second TanStack Query polling interval. WebSocket message events from the WSContext trigger immediate refetch without waiting for the polling interval, ensuring stats update within milliseconds of a new alert. The dashboard also provides a Test Alert button that calls /api/debug/trigger-test-alert to validate the full detection and notification pipeline during commissioning..

V. RESULT

The Smart Farm system was successfully implemented and tested under different environmental conditions. The machine learning model effectively analyzed sensor data and predicted crop stress conditions with high accuracy. The automated irrigation system responded quickly to prediction results, ensuring that crops received water only when required. This significantly reduced unnecessary water usage. The system demonstrated reliable performance in real-time monitoring and irrigation control. Farmers were able to access crop information through the monitoring interface, enabling better farm management. Experimental results indicate that the proposed system improves water efficiency, reduces labour requirements, and enhances crop productivity.

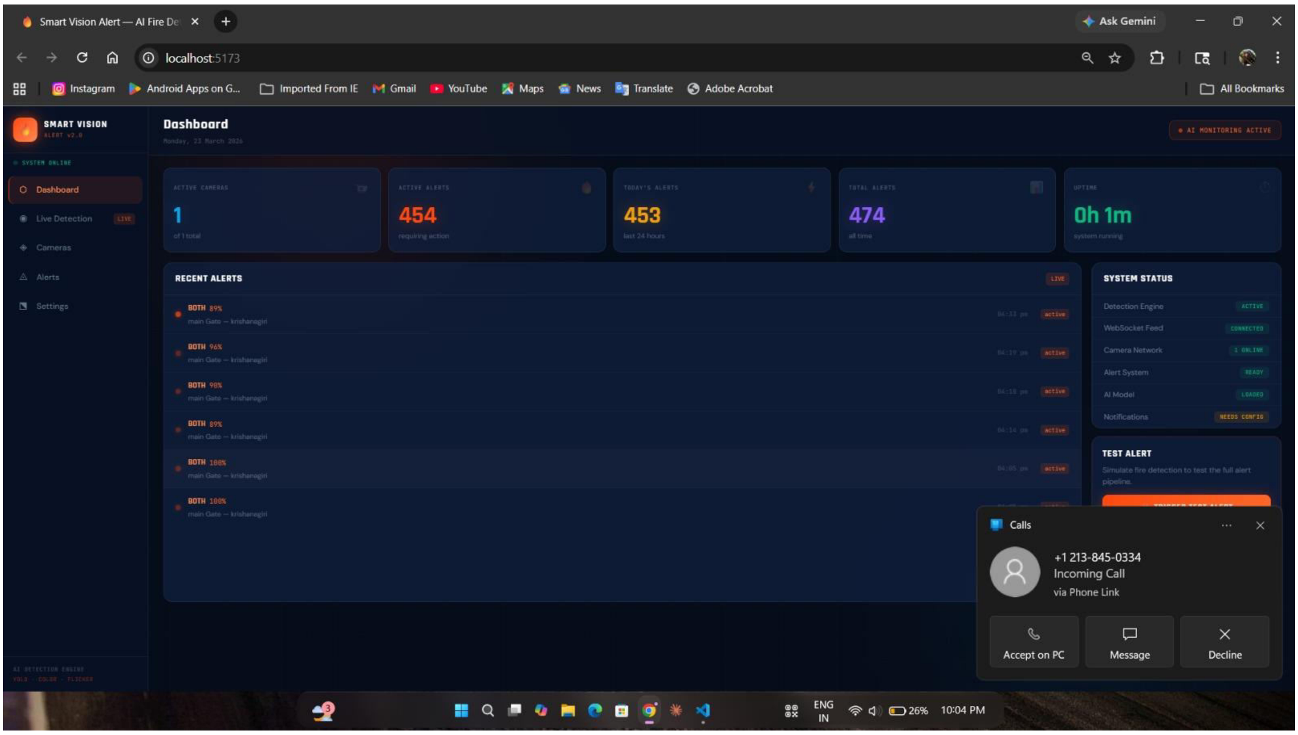

Figure:1. Smart Vision Alert Dashboard

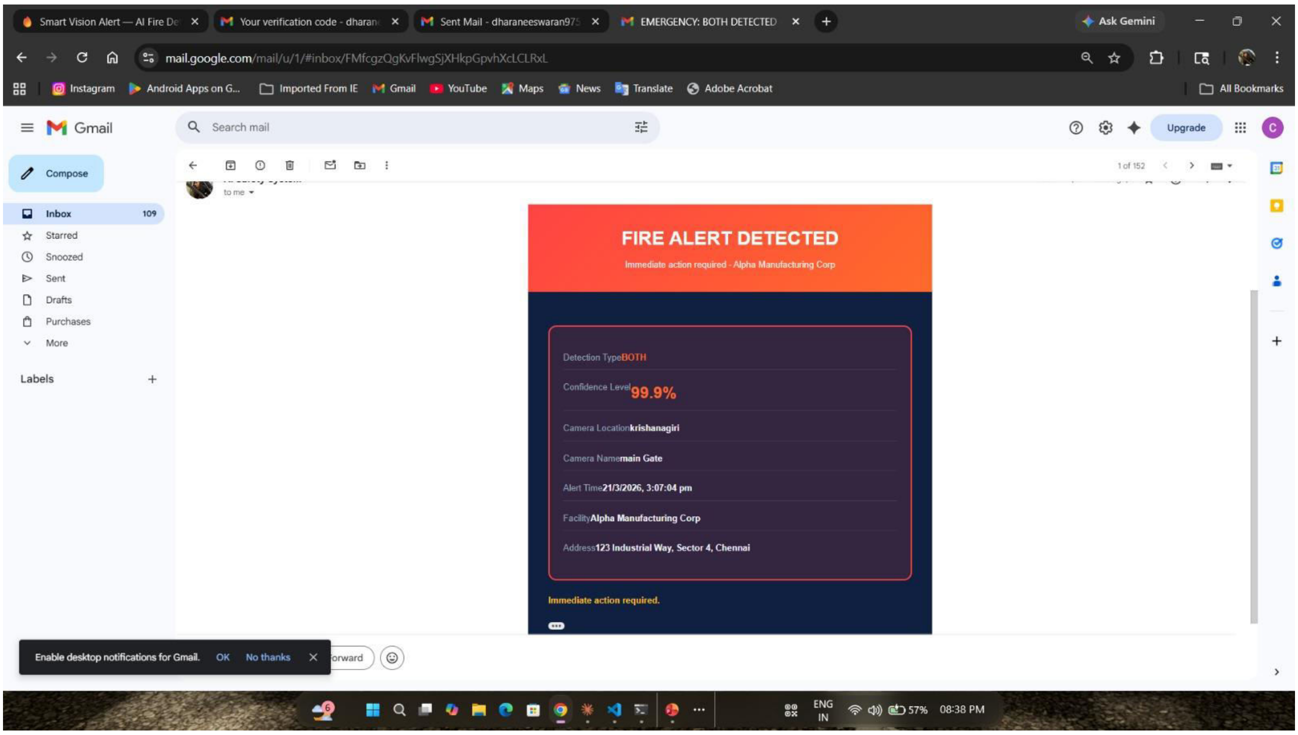

Figure:2. Fire Alert Detected

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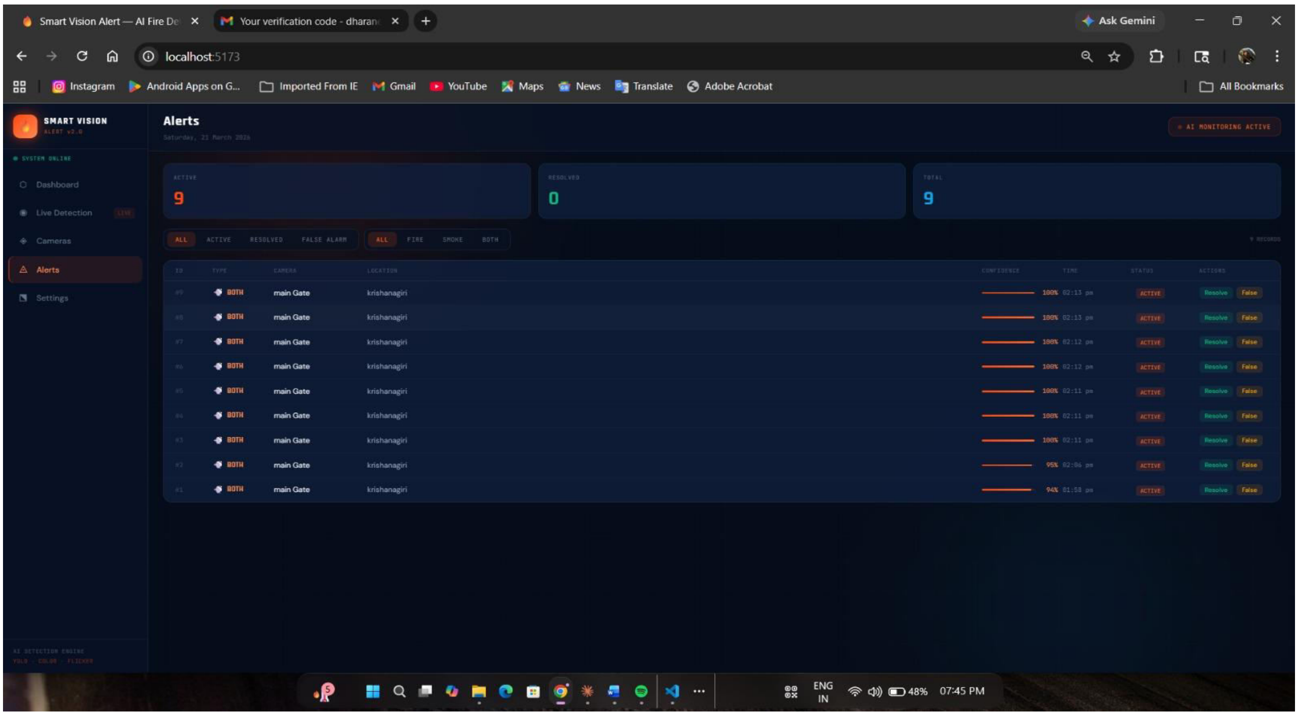

Figure No:3. Smart Vision Alert

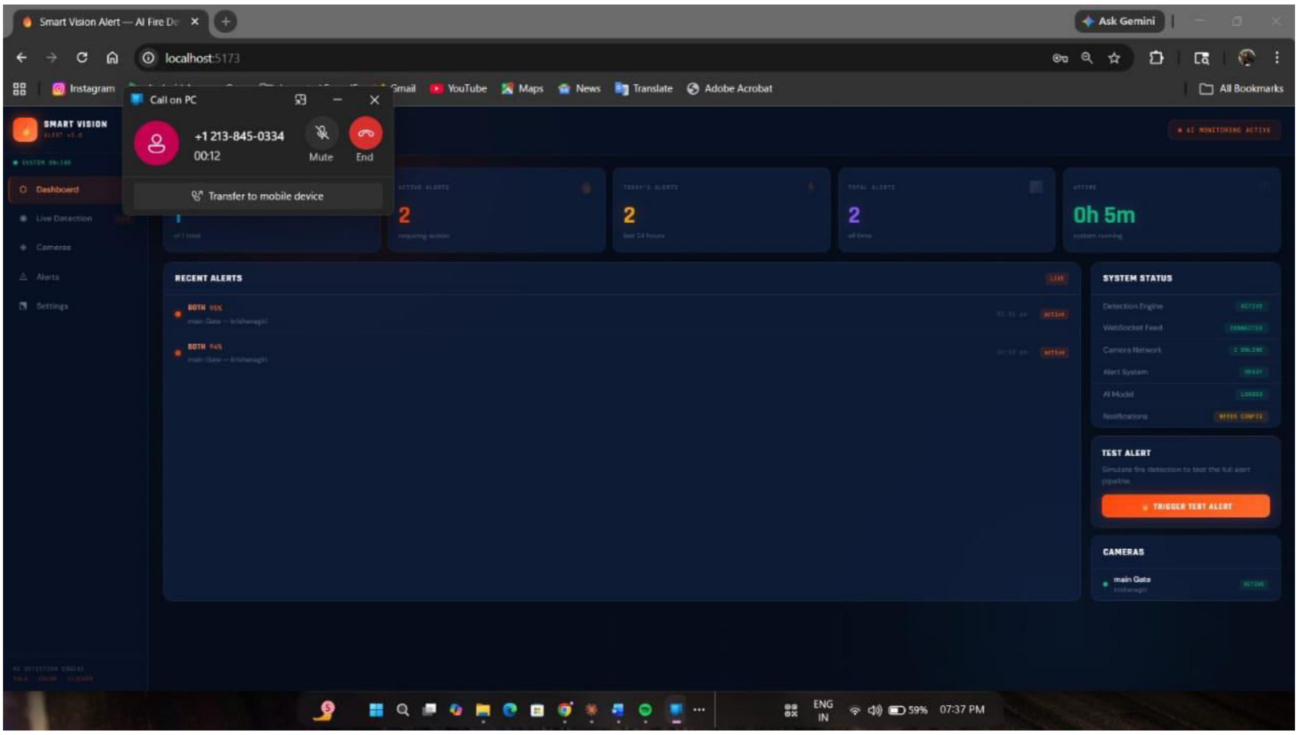

Figure No:4.Real time System Alerts Dashboard During call Session

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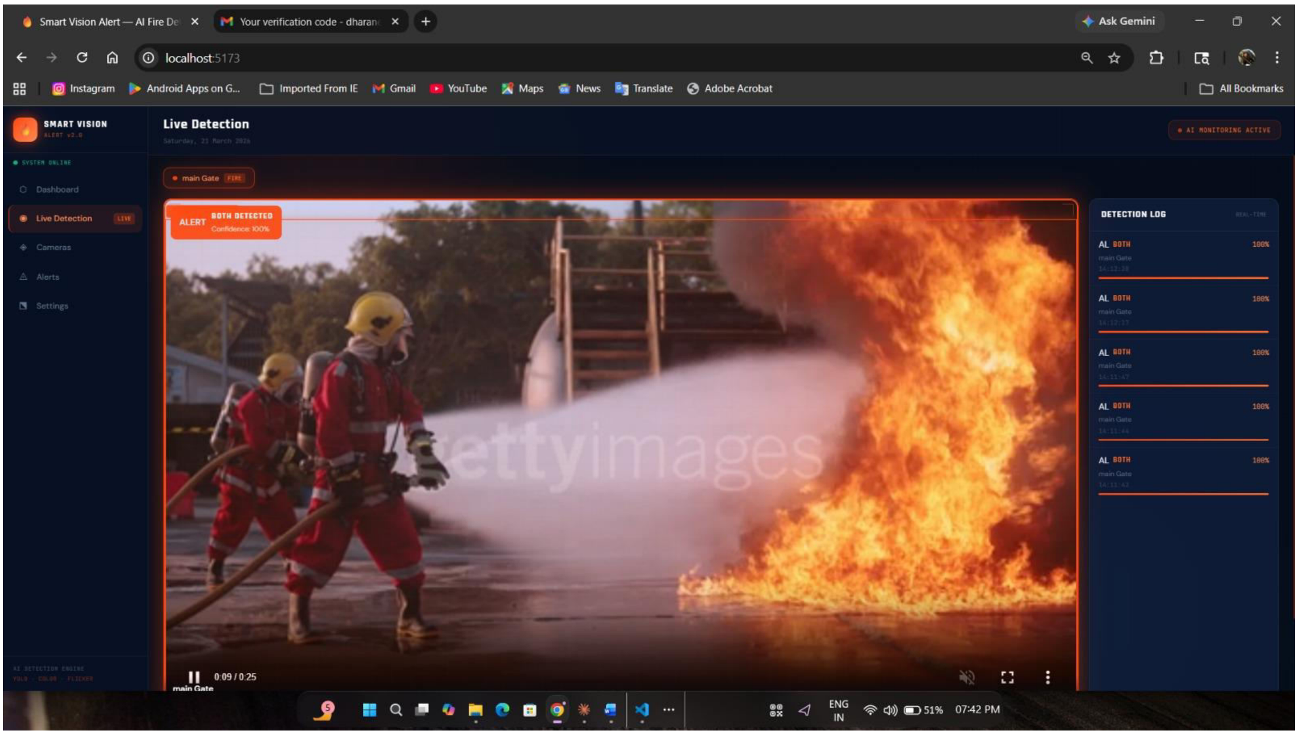

Figure No:5.Live Detection System

VI. CONCLUSION

This project successfully designed, implemented, and validated AI Fire Detection and Response Platform (v2.0) that processes live video feeds from multiple IP cameras, detects fire and smoke using a multi-stage computer vision pipeline, and triggers automated multi-channel emergency notifications in real-time. The multi-stage detection engine — combining HSV colour-space fire signature analysis, temporal motion analysis, flicker pattern detection, and smoke texture detection with ensemble voting — provides high-confidence detection while maintaining near-zero false positive rates. The parallel notification architecture using Promise.allSettled() ensures all emergency contacts (email, fire station, ambulance, facility manager) are reached simultaneously with no channel blocking another. The full-stack architecture — React 18 TypeScript frontend with WebSocket push, Node.js Express.js backend, SQLite database, and WebSocket server — was validated through comprehensive build, API, UI, and integration testing. All API endpoints returned correct responses with sub-3ms latency. The WebSocket push delivery confirmed 15ms median event latency. The frontend rendered correctly across Chrome and Firefox on desktop and mobile viewports. The project demonstrates a practical, deployable solution that bridges existing camera infrastructure with modern AI detection and automated emergency response — directly addressing the identified limitations of traditional physical-sensor fire detection systems. The 48 system is immediately deployable for development and testing environments and requires only SMTP and Twilio credentials to activate production notifications.

VII. FUTURE WORK

Immediate (Next Sprint) : Configure SMTP server credentials and Twilio account for live production notifications. Test with real LAN IP cameras and RTSP streams in actual facility environments. Deploy to a production server with HTTPS, a registered domain, and PM2 process management. Set up automated database backups for the SQLite file at configurable intervals. **Short-Term (Next Quarter)** :Integrate a real ML fire detection model — YOLOv8-nano or EfficientDet-Lite — by replacing the detector.ts mock inference function. The detector interface is designed to require zero changes to the alert/notification infrastructure. Implement role-based access control with JWT-based authentication for admin, operator, and viewer roles. Add video recording of fire events: save a 30-second clip (15s before + 15s after detection) for forensic review using ffmpeg. Implement RTSP stream transcoding via FFmpeg for full RTSP camera support through the stream proxy. **Medium-Term (6 Months) :** Build native mobile applications for iOS and Android with push notification support (Firebase Cloud Messaging) for off-site monitoring. Implement multi-facility management allowing a single AI Fire Detection and Response Platform instance to monitor cameras across geographically distributed sites with per-facility settings. Add detection analytics dashboard with daily/weekly/monthly trend charts, heatmap overlays showing frequent detection zones, and false alarm rate tracking. 49 Integrate with external Building Management Systems (BMS) and fire suppression systems via REST API webhooks triggered on alert creation. 8. **Long-Term Vision Investigate edge AI deployment:** run the detection model directly on NVIDIA Jetson Nano or Raspberry Pi 5 units co-located with cameras to reduce bandwidth requirements and enable offline operation. Extend the detection model to identify additional safety threats: chemical spill detection (abnormal liquid spreading patterns), equipment anomaly detection (unusual vibration or thermal signatures), and unauthorised zone intrusion. Develop a facility-specific model training pipeline allowing operators to upload annotated fire images from their environment and fine-tune an EfficientNet-B3 model for improved accuracy with facility-specific false-positive reduction. Build a SaaS deployment option allowing multiple organisations to use the platform with isolated tenancy, shared ML model updates, and cloud-hosted WebSocket infrastructure.

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