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Next-Gen Fire Safety: Intelligent Alert Systems and AI-Powered Compliance Verification

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Abstract - *Urban infrastructure must comply with fire safety regulations, but the current manual, ineffective, and human error-prone inspection and approval procedures are still in place. An AI-powered system that automates real-time emergency alerting, NOC (No Objection Certificate) issuance, and fire safety compliance verification is proposed in this paper. The system incorporates EasyOCR for text extraction from compliance documents, BERT (Bidirectional Encoder Representations from Transformers) for natural language processing to verify regulatory compliance, and YOLO (You Only Look Once) for identifying critical fire safety equipment in uploaded images. Additionally, to improve response efficiency during emergencies, Firebase Cloud Messaging is used to send real-time alerts to fire departments. Delays are reduced, regulatory compliance is guaranteed, and emergency preparedness is enhanced by automating fire safety inspections and compliance verification. By offering an intelligent, data-driven solution that lessens reliance on humans and improves public safety, the suggested system seeks to completely transform fire safety management.*

Key Words: Deep Learning , Smart Fire management System, YOLO (You Only Look Once), EasyOCR, BERT, Fire Safety Automation, AI in Emergency Response.

1.INTRODUCTION

Ensuring the protection of buildings, infrastructure, and human life depends heavily on fire safety compliance. Strict adherence to fire safety regulations is required by regulatory agencies. This includes having valid compliance paperwork and the necessary fire safety equipment, such as sprinklers, exits, alarms, and fire extinguishers. However, the manual, labor-intensive, and human error-prone nature of traditional fire safety inspection and No Objection Certificate (NOC) issuance processes results in inefficiencies and possible safety hazards. Delays in responding to fire situations can also lead to serious injuries and monetary losses. An AI-driven strategy for fire safety management is required due to the growing complexity of urban growth and the need for quicker and more precise compliance verification.

A revolutionary way to automate fire safety compliance, inspections, and real-time alarm production is provided by the quick developments in artificial intelligence (AI), computer vision, natural language processing (NLP), and the Internet of Things. In order to increase the efficiency of emergency response, automate compliance verification, and improve inspection accuracy, this study suggests an intelligent fire safety management system that makes use of several AI technologies. It incorporates:

- **YOLO (You Only Look Once)** for real-time detection of fire safety equipment in images uploaded by users. This ensures that all required safety measures are in place before issuing an NOC.
- **EasyOCR** for extracting textual information from compliance documents, allowing automated verification without manual intervention.
- **BERT (Bidirectional Encoder Representations from Transformers)** for analyzing extracted text and matching it against official fire safety regulations, ensuring adherence to government norms.
- **Firebase Cloud Messaging (FCM)** for real-time alert generation in case of fire incidents, sending immediate notifications to the fire department with location data and incident images for quicker response.

Traditional fire safety management issues including manual paperwork, phony NOC approvals, inspection delays, and poor emergency response are all addressed by the suggested method. The solution lowers the risk of non-compliance and improves regulatory enforcement by automating fire safety inspections and NOC clearances. Its real-time fire detection and alert system also enhances emergency readiness, allowing fire departments to react quickly and avert possible catastrophes. This research advances the creation of a more effective, scalable, and proactive fire safety system by integrating AI-driven automation into fire safety compliance, thereby enhancing public safety and regulatory transparency.

1.1 Literature Review

Fire safety management has advanced considerably with the inclusion of Artificial Intelligence (AI), Internet of Things (IoT), and deep learning models. Numerous studies have researched AI-based solutions for fire detection, verification of compliance, and automation of emergency response. This section discusses recent developments in smart fire safety systems.

Bakas and Kontoleon [1] proposed the Intelligent Fire Engineering Tool (IFETool), a deep learning fire simulation platform for large open areas like atriums. Their system delivers 97% accuracy in forecasting fire behavior, such as visibility of smoke, temperature, and CO concentration, providing a less expensive alternative to conventional Computational Fluid Dynamics (CFD) simulations. IFETool facilitates real-time fire safety analysis, enhancing performance-based fire design and emergency response planning.

Surabhi KS and Babu [2] created an AI-driven fire detection system based on Convolutional Neural Networks (CNNs) and Support Vector Machines (SVMs) for fire detection. The system combines IoT-based real-time monitoring, triggering automated alarm and fire suppression. In comparison to conventional smoke detectors, the method minimizes false alarms and increases precision. Future improvements also involve drone-based surveillance of fires and predictive analytics for assessing fire danger.

Advancements in AI-based structural fire safety assessments have also been explored. Bakas and Kontoleon [3] demonstrated how Artificial Neural Networks (ANNs) and Support Vector Machines (SVMs) can predict fire-induced structural damage in concrete, steel, and timber buildings. Their study highlights AI's role in enhancing heat transfer modeling and spalling prediction for improved building resilience. Future research aims to integrate real-time fire monitoring with Digital Twins to enhance safety compliance.

For smoke and wildfire detection, Bahhar et al. [4] constructed a YOLO-based deep learning model to identify wildfires earlier with 99% accuracy. The research prioritized the identification of smoke instead of fire since earlier detection of smoke allows prompt emergency response and mitigation of the risk. The suggested system can be applied in drone-supported surveillance for fire as well as in real-time observation using edge AI deployment.

AI has also been utilized to verify fire safety compliance automatically. Parekh [5] put forward an AI-based Fire No Objection Certificate (NOC) issuance system, which leverages Natural Language Processing (NLP) models to interpret building codes and fire regulations. This automated compliance categorizes buildings into low, medium, and high-risk categories, facilitating simplified fire safety verification. Future work entails the use of blockchain technology for secure regulatory documents and compliance tracing.

IoT-furnaced fire detection and suppression systems have also been researched. Khan [6] proposed a thermal camera-based fire detection system combining deep learning models and IoT sensors to identify fires automatically and suggest suitable extinguisher classes (A, B, C, D, K). This method increases fire suppression effectiveness, minimizes false alarms, and maximizes emergency response time. Extensions in the implementation of edge AI are focused on enhancing real-time fire detection in smart buildings.

Bayer and Aziz [7] investigated the application of YOLOv5 for detecting fire safety equipment in buildings, airports, and industrial sites. Their framework enables automated verification of compliance by identifying fire extinguishers, smoke detectors, and emergency exits with an accuracy of 80.1% at 51.5 FPS real-time processing. The work emphasizes the necessity of incorporating AI-driven Building Information Modeling (BIM) for automated fire safety inspections.

NLP-based compliance checking has been further improved by Xiaorui Xue [8], who created an AI-driven fire safety code extraction system. Their system improves compliance accuracy, enhancing fire code checking from 89.13% to 96.85%. The research points out the contribution of deep learning-driven POS tagging in the automation of fire risk assessment and evacuation planning.

In the field of automated fire protection, Le et al. [9] introduced an AI-based Fire Detection and Prevention System (FDPS) integrating YOLOv4 object detection and IoT-activated fire suppression systems. Their system provides 90% accuracy in fire detection and automatically puts out small fires in 30 seconds. Real-time notification through IoT networks also improves emergency readiness.

Likewise, Tailor et al. [10] implemented an AI-driven Fire NOC approval system that utilizes deep models of learning (Random Forest, Decision Trees, and Neural Networks) to gauge fire hazards within buildings. Tailor et al.'s automation compliance

system lowers the risk of delays and counterfeiting certification, guaranteeing better regulatory execution and safety regulation. Future innovation involves AI-directed evacuation mapping as well as emergency response planning.

Hu et al. [11] proposed YOLO-LF, a light YOLO-family fire detection model that enhances real-time fire monitoring efficiency. The model uses StarNet as the backbone and an EfficientDet detection head, achieving 4.3% improved accuracy compared to YOLOv8, 40% fewer parameters, 30% reduced computational complexity, and 41% improved FPS. YOLO-LF achieves strong detection in smoky scenes, which makes it applicable to industrial fire protection, wildfire monitoring, and security monitoring scenarios.

Together, the reviewed studies demonstrate how crucial cloud-based, IoT, and AI solutions are to transforming fire safety management. However, existing research lacks a fully integrated approach that combines YOLO-based object detection, EasyOCR for document verification, and BERT for compliance matching. By suggesting an AI-powered system that automates NOC generation, fire safety inspections, and real-time alerting, our research seeks to close this gap and guarantee a thorough and effective fire safety framework.

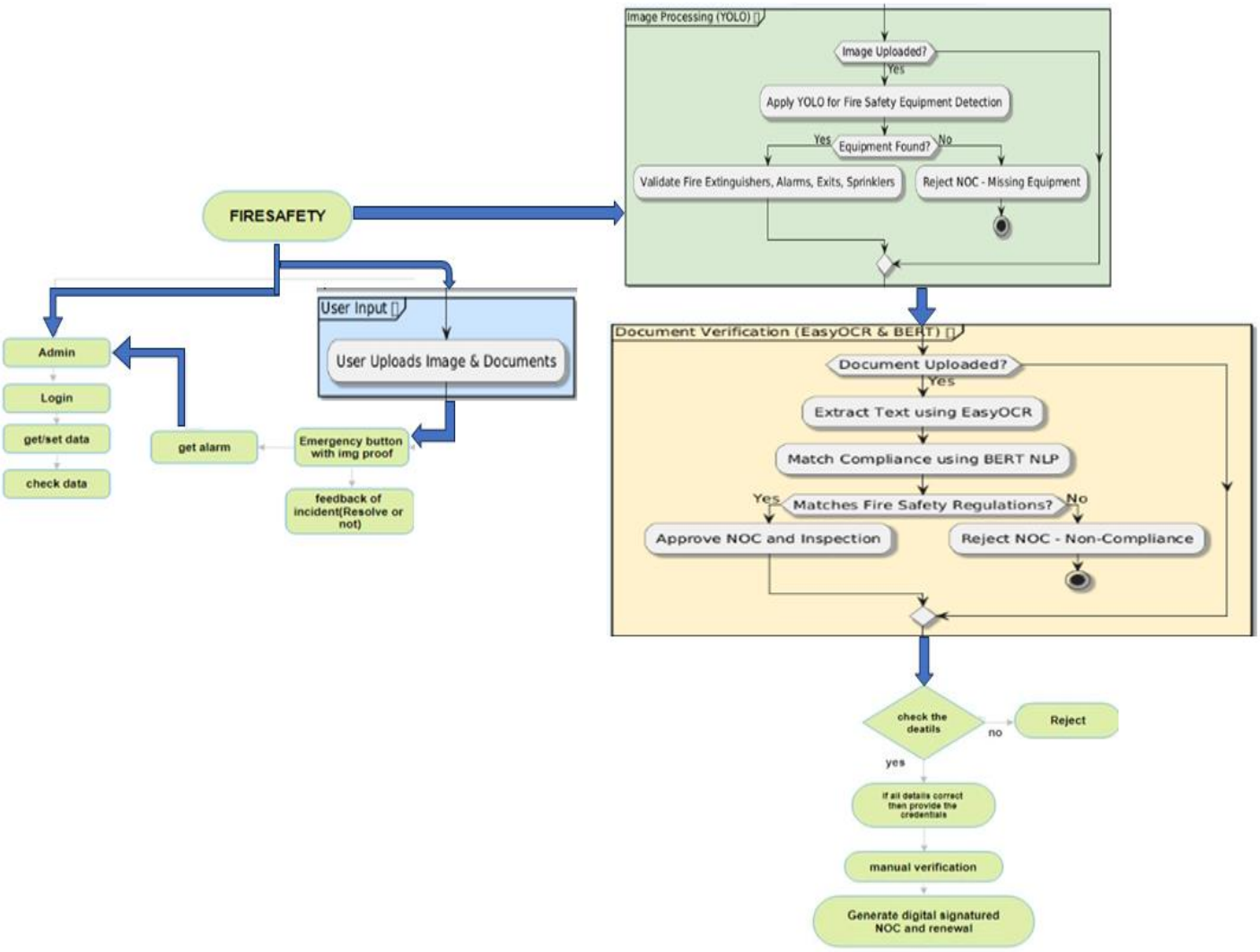

Fig -1: ILLUSTRATES THE COMPREHENSIVE WORKFLOW OF THE FIRESAFETY APP, OUTLINING THE FIRE DETECTION, IMAGE PROCESSING, AND DOCUMENT VERIFICATION PHASES.

2. METHODOLOGY

The FireSafety App simplifies fire safety inspections, automates NOC approvals, and improves emergency response with AI and real-time notifications. The system initiates with YOLO-based fire detection, consistently evaluating video feeds to recognize flames or smoke. When detection occurs, it records the event in a MySQL database and activates emergency alerts via Firebase

Cloud Messaging (FCM), informing the fire department and property owners with location and timestamp information for prompt response. This process is depicted in Fig. 1.

For NOC approvals, users submit documents, which are processed using EasyOCR to extract text and BERT NLP to confirm compliance. If the document adheres to fire safety regulations, the system automatically approves the NOC; if not, the applicant is alerted to the required corrections. Concurrently, YOLO object detection verifies the presence of fire safety equipment, including extinguishers and alarms, denying applications that lack essential items.

In emergencies, FCM notifications deliver location-specific alerts along with evacuation instructions. The backend, developed with Spring Boot, proficiently manages fire reports, compliance documentation, and user data through RESTful APIs, while AWS/GCP deployment with Docker and Kubernetes guarantees scalability. By combining AI-driven verification, automated compliance assessments, and real-time alerts, the FireSafety App revolutionizes fire safety management, minimizing risks and ensuring adherence to regulations.

2.1 YOLO (You Only Look Once) Algorithm

1. **Image Input**: A picture I with dimensions $W \times H$ W×H is captured by the system.

2. **Feature Extraction**: Feature maps F are extracted from I via a CNN backbone (such as Darknet).

3. **Grid segmentation**: involves splitting the image into a S×S grid with B bounding boxes (x, y, w, h) predicted by each cell and confidence ratings (C).

4. **Identifying objects**: Class probabilities $P(c|O)$ P(c|O), confidence $C = P(O) \times IOU$ C=P(O)×IOU, and final detections using non-max suppression (NMS) are output by each bounding box as depicted in Fig.2.

4. **Alert Trigger**: The fire department receives an emergency alert with image proof if fire or hazard (P fire > θ) is detected.

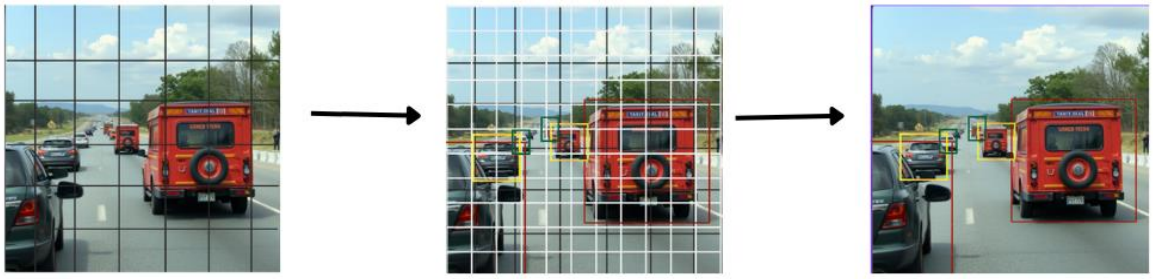

Fig -2: YOLO IS A POPULAR AND FAST OBJECT DETECTION ALGORITHM THAT USES A SINGLE NEURAL NETWORK TO PREDICT BOUNDING BOXES AND CLASS PROBABILITIES FOR OBJECTS IN AN IMAGE

2.2 Easy OCR for Documentation Verification

1.**Image Input**: A picture of a document is taken or uploaded.

2.**Preprocessing**: Noise reduction, scaling, and grayscale conversion are applied to the image.

3.**Text Detection**: Text regions are detected via a deep learning-based model (CTPN or EAST).

4.**Text Recognition**: Convolutional Recurrent Neural Networks, or CRNNs, extract features and decode text by using the formula T={t 1,t 2,...,t n } as shown in fig.3.

5.**Post-processing**: Spell-checking and alignment methods are used to fix the detected text.

6.**Validation**: To ensure validity, extracted text T is compared to pre-made templates or databases.

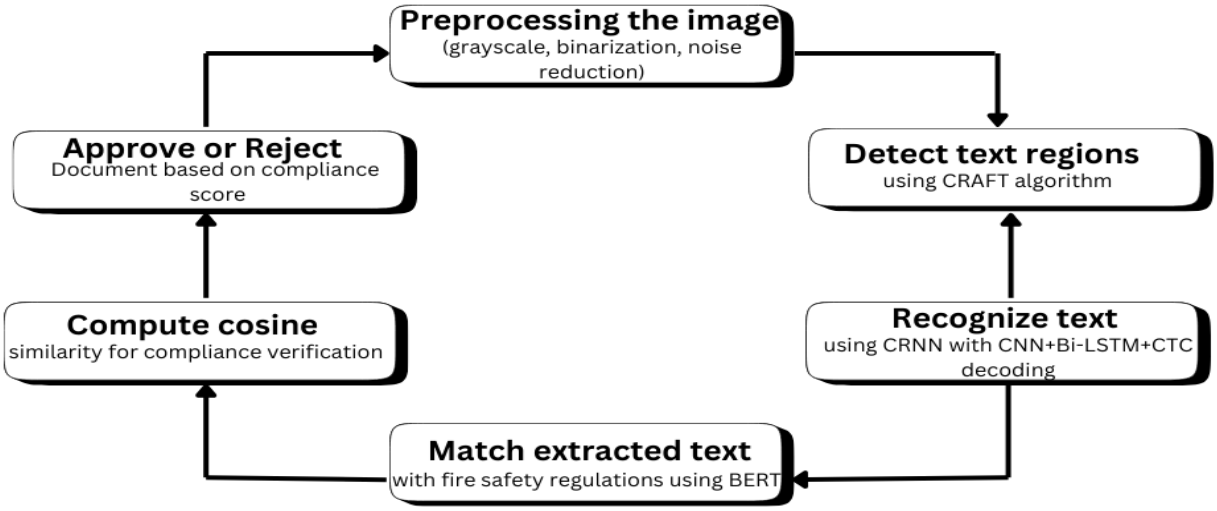

Fig -3: EASYOCR IS A POWERFUL AND ACCESSIBLE OCR LIBRARY THAT USES DEEP LEARNING MODELS AND VARIOUS TECHNIQUES TO EXTRACT TEXT FROM IMAGES.

2.3 BERT Algorithm

1.**Text Input**: WordPiece is used to tokenize the captured text T from EasyOCR into subwords.

2.**Embedding Generation**: Vector representations of tokens $E \in Rd$ E ∈R d are created.

3.**Contextual Analysis**: BERT uses multi-head attention layers and self-attention (Q, K, V) to process embeddings.

4.**Classification**: A softmax layer determines whether a document is fake (P fraud) or legitimate (P valid).

5.**Making Decisions**: The document is accepted if P valid > θ P valid > θ; if not, it is marked for review.

This AI model automates fire safety inspections by detecting safety equipment with YOLO, extracting text with OCR, and verifying compliance using BERT NLP as depicted in Fig. 4. After integrating FCM notifications, it now provides real-time alerts for missing equipment or non-compliance, enhancing fire safety monitoring.

3. CONCLUSIONS

The Fire Department Management System (FDMS) was created to use automation and artificial intelligence (AI) to improve the effectiveness and precision of fire safety management. To expedite procedures including NOC issuing, fire safety inspections, emergency response, and data management, the system incorporates a number of digital technologies. The findings show enhanced regulatory compliance, faster response times, and a notable decrease in manual errors.

The capacity of FDMS to automate NOC approvals, which shortens the time needed to secure fire safety certificates, is one of its most noteworthy results. The solution reduces the need for human intervention by utilizing AI-driven verification procedures. Putting in place a real-time emergency response system has also been very successful because it allows for real-time tracking, location-based alerts, image uploads, and quick event reporting. Because it offers safe storage and convenient access to fire safety records, inspection data, and compliance history, the consolidated digital platform greatly enhances data management. This lowers the possibility of inconsistencies and data loss by ensuring that fire departments can keep correct and current information. Additionally, proactive fire risk management is made possible by AI-powered predictive analysis, which assists authorities in anticipating possible fire threats based on past trends and environmental circumstances.

However, adequate implementation, user training, and regular software updates are necessary for FDMS to be effective. Because firemen and administrative staff need to feel at ease using the system for day-to-day operations, user acceptance is crucial to its success. The findings show that FDMS can revolutionize fire safety management by making it more effective, data-driven, and emergency-responsive.

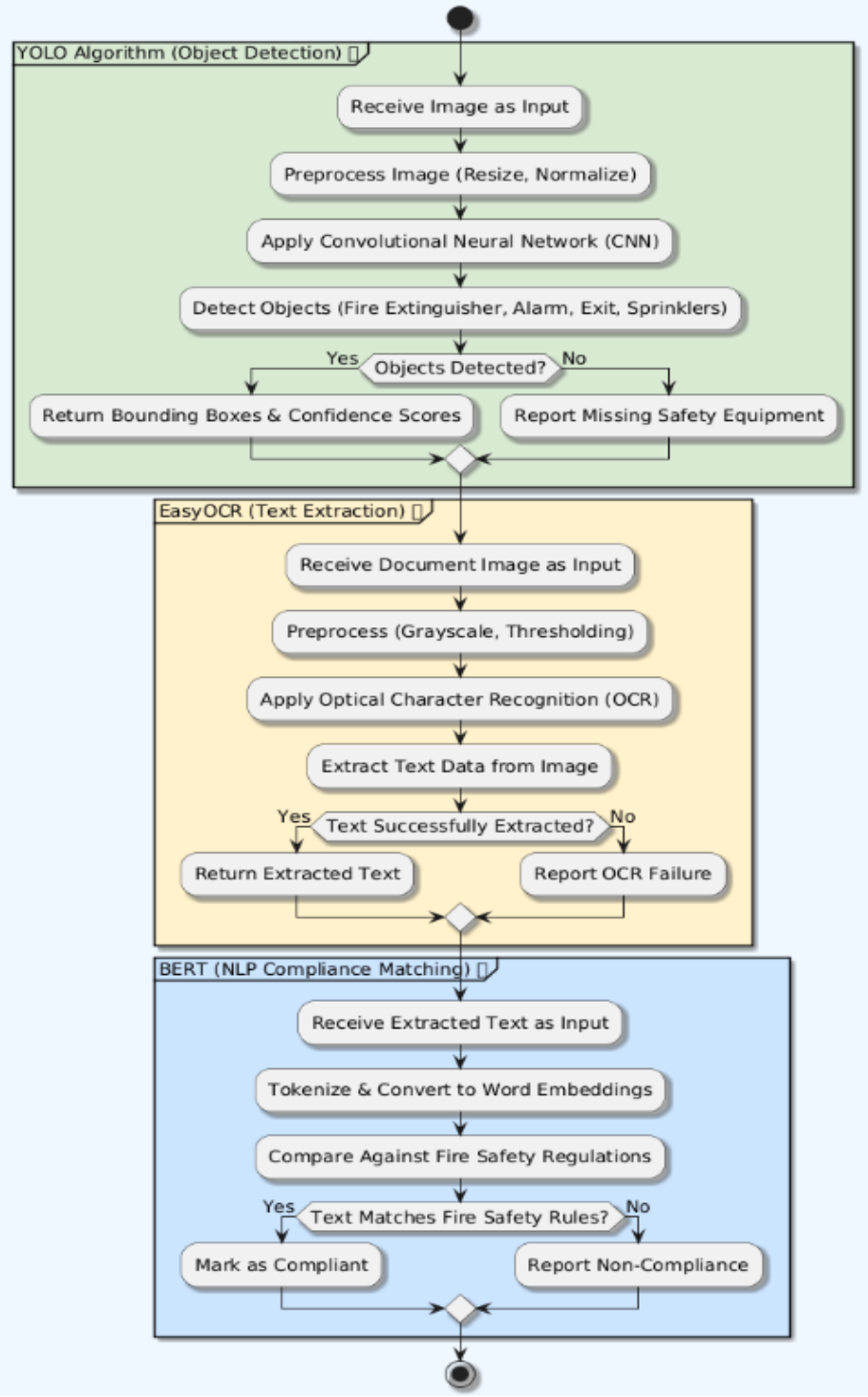

Fig -4: AUTOMATED FIRE SAFETY INSPECTION WORKFLOW USING YOLO, OCR, AND BERT.

3.1 Challenges and Limitations

Even though the Fire Department Management System has many advantages, its successful deployment and long-term use require addressing a number of issues and constraints.

High Initial Investment Costs: The deployment of FDMS necessitates a significant outlay of funds for cloud infrastructure, AI model training, software licenses, and employee training. Widespread adoption may be hampered by smaller fire departments' inability to pay for such expenditures.

Dependency on Technology: FDMS is highly dependent on hardware infrastructure, cloud services, and internet access. Poor connectivity and power outages might impair system performance in rural or disaster-affected areas, reducing its usefulness in emergency situations.

User Adoption and Training: Firefighters and administrative staff must receive the appropriate training when switching from manual to entirely digital processes.

Cybersecurity Risks: FDMS is susceptible to cyberattacks since it houses confidential fire department information, such as incident reports, compliance documents, and operational specifics. Strong encryption, multi-layered authentication, and frequent security audits are necessary to guard against data breaches and unwanted access to the system.

AI Model Accuracy and Maintenance: The precision and dependability of machine learning models are essential for AI-driven automation, including predictive analytics and NOC approvals. To maintain optimal system performance and avoid making poor decisions, regular updates, data validation, and algorithm fine-tuning are necessary.

Notwithstanding these drawbacks, FDMS can be enhanced over time by calculated infrastructure expenditures, cybersecurity safeguards, and user training. Some of these difficulties can be lessened by putting emergency procedures, offline functionality, and backup systems into place.

3.2 Result and Future Scope

By resolving major inefficiencies in conventional procedures, the Fire Department Management System represents a substantial leap in fire safety management. FDMS improves decision-making, lowers manual error rates, and increases fire readiness by combining AI-powered automation, real-time emergency response, and centralized data management. The system is a game-changer for contemporary fire departments since it can automate fire safety inspections, expedite NOC issuing, and offer real-time event reporting. However, FDMS adoption success hinges on resolving operational, budgetary, and technological obstacles. Sufficient resources, educational initiatives, and ongoing system upgrades are required to guarantee broad adoption and long-term viability. Maintaining the system's dependability also requires addressing cybersecurity threats and making sure AI models are accurate.

All things considered, FDMS is a major advancement in fire safety management, providing a scalable and effective solution that improves emergency response and regulatory compliance. Continuous advancements in technology will be required to meet new fire safety requirements and optimize the system's ability to protect communities.

FDMS has the ability to be significantly improved through a variety of technical integrations and developments as fire safety concerns continue to change. Among the crucial areas for further advancement are:

Predictive analytics powered by AI: Sophisticated AI models can be trained to examine data from previous fire incidents, identify trends, and forecast high-risk regions. This can assist fire departments in taking action before crises arise.

Integration with IoT Devices: By linking FDMS to IoT-enabled thermal sensors, smoke detectors, and fire alarms, real-time data on fire dangers may be obtained, enabling authorities to respond quickly before situations get out of hand.

Mobile App Improvements: To help firefighters navigate dangerous situations, future iterations of the FDMS mobile applications may incorporate voice-command capabilities, real-time video feeds, and augmented reality (AR) technologies.

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