

SmartInspect AI: AI-Driven System for Secure Fire Safety Inspection and NOC Automation

Sahil Kavatkar Department of Computer Engineering Atharva College of Engineering, Mumbai, India sahilkavatkar-cmpn@atharvacoe.ac.in	Amit Gupta Department of Computer Engineering Atharva College of Engineering, Mumbai, India amitgupta-cmpn@atharvacoe.ac.in	Sagar Mandigam Department of Computer Engineering Atharva College of Engineering, Mumbai, India sagarmandigam-cmpn@atharvacoe.ac.in	Suraj Mandigam Department of Computer Engineering Atharva College of Engineering, Mumbai, India surajmandigam-cmpn@atharvacoe.ac.in	Prof, Pranali Bhusare Asst. Professor Department of Computer Engineering Atharva College of Engineering, Mumbai, India parnalibhusare@atharvacoe.ac.in
---	---	---	---	---

Abstract: The traditional Fire No Objection Certificate (NOC) inspection process is largely manual, time-consuming, and prone to errors and data manipulation, which can compromise public safety. This paper presents SmartInspect AI, an intelligent and secure inspection system that leverages Artificial Intelligence and sensor-based validation to modernize fire safety compliance. The proposed system integrates geo-tagging, timestamp verification, barometric floor detection, perceptual image hashing, and audio-based fire alarm verification to ensure authenticity and reliability of inspection data. A mobile application enables field officers to capture real-time evidence, while a centralized backend processes and stores the data securely, and an administrative dashboard facilitates efficient monitoring and decision-making. By introducing tamper-proof data collection and multi-layered verification, the system enhances transparency, reduces fraud, and accelerates the NOC approval process. The solution is scalable, cost-effective, and aligned with smart governance initiatives such as Digital India, making it a practical approach for improving fire safety inspection systems.

A mobile application is used by field officers to capture real-time inspection data, while a centralized backend processes and stores the information securely. Additionally, an administrative dashboard enables authorities to review structured data and make informed decisions efficiently by introducing tamper-proof data collection and AI-assisted validation, the proposed system reduces fraud, enhances accountability, and accelerates the NOC approval process. The solution is scalable, cost-effective, and aligned with smart governance initiatives such as Digital India and Smart Cities.

Keywords: Fire Safety, Artificial Intelligence, Image Hashing, Geo-Tagging, Audio Analysis, Smart Inspection, NOC Automation

1. INTRODUCTION

Fire safety regulations are essential for maintaining secure building environments and preventing hazardous incidents in urban areas. Authorities are responsible for verifying compliance before granting operational approvals such as Fire NOC certificates. Municipal authorities conduct inspections to verify that buildings meet prescribed fire safety standards before issuing a Fire No Objection

Certificate (NOC). However, the existing inspection process is largely manual, involving paperwork, static images, and physical verification, which makes it time-consuming and inefficient. The absence of real-time validation mechanisms further reduces the reliability of inspections and creates challenges in maintaining transparency.

One of the major limitations of the current system is the lack of proper verification of inspection activities. There is

no reliable way to confirm whether an officer has visited the actual site, inspected all floors, or captured genuine data during the process. Static images can be reused, reports can be manipulated, and there is minimal accountability in the workflow. These issues not only delay the NOC approval process but also increase the risk of unsafe buildings being approved, thereby posing serious threats to public safety.

To overcome these challenges, this research proposes **SmartInspect AI**, an intelligent and automated inspection system that integrates Artificial Intelligence with sensor-based validation techniques. The system utilizes geo-tagging, barometric sensors for floor detection, image hashing for tamper prevention, and audio analysis for fire alarm verification to ensure authenticity and accuracy. By digitizing the entire inspection workflow and introducing multi-layered verification, the proposed solution enhances efficiency, transparency, and reliability in fire safety compliance, contributing to safer and smarter urban infrastructure.

2. LITERATURE REVIEW

Recent advancements in smart governance and digital inspection systems have encouraged the use of mobile and Artificial Intelligence (AI)-based solutions to improve safety compliance processes. Several studies have explored different technologies such as image validation, sensor-based localization, and automated reporting systems to enhance inspection efficiency and reliability.

A study by Wang et al. (2022) proposed a mobile-based inspection framework for infrastructure monitoring, where field data is collected using smartphones and uploaded to cloud servers for analysis. While the system improved data accessibility and reporting speed, it lacked mechanisms to verify the authenticity of captured data, making it vulnerable to manipulation.

Research by Dabove et al. (2019) focused on indoor localization using barometric pressure sensors to estimate floor levels within multi-story buildings. The study demonstrated that barometric readings can effectively determine vertical movement with reasonable accuracy. However, this approach was primarily used for navigation and was not integrated into inspection or compliance verification systems.

In the field of image security, Monga and Evans (2006) introduced perceptual image hashing techniques to detect duplicate or altered images. These methods are efficient for identifying image tampering but are generally used in

isolation and do not incorporate contextual information such as location, time, or user identity.

Another study by Salamon and Bello (2017) explored environmental sound classification using machine learning techniques such as MFCC (Mel-Frequency Cepstral Coefficients). Their work demonstrated high accuracy in recognizing sound patterns, but its application in real-time safety verification, such as fire alarm validation, remains limited.

Additionally, Zhang et al. (2021) proposed a cloud-based smart monitoring system that uses IoT devices for real-time data collection in urban environments. Although the system improved monitoring capabilities, it required dedicated hardware infrastructure, increasing deployment cost and complexity.

Research by Patel and Shah (2022) explored the use of geo-tagged images for monitoring urban infrastructure. While geo-tagging provided location-based validation, the study did not incorporate additional verification layers such as floor-level detection or protection against image reuse, leaving scope for manipulation.

Research Gap

From the above studies, it is evident that existing solutions focus on individual components such as image validation, location tracking, or audio analysis, but lack integration into a unified system. Most systems do not provide multi-layer verification, which is essential for ensuring data authenticity in safety-critical applications. Furthermore, there is limited use of combined sensor data (geo-location, barometric pressure), AI-based image validation, and audio verification within a single inspection workflow.

The proposed SmartInspect AI system addresses these limitations by integrating multiple technologies into a single platform. It provides end-to-end verification through geo-tagging, floor-level detection, image tamper prevention, and AI-based fire alarm analysis, thereby ensuring a secure, transparent, and reliable fire safety inspection process.

3. METHODOLOGY

The SmartInspect AI system is developed using a structured and modular approach that combines mobile technology, backend services, sensor-based validation, and Artificial Intelligence to ensure a secure and reliable fire

safety inspection process. Initially, system requirements were identified based on the limitations of traditional manual inspections, such as lack of verification and data authenticity. A client-server architecture was then designed, consisting of a Flutter-based mobile application for field inspectors, a Node.js backend for data processing, and Python-based microservices for AI analysis.

The mobile application captures geo-tagged images, timestamp data, audio recordings, and barometric pressure readings to verify inspection location and floor level. To prevent data manipulation, multi-layer validation techniques are applied, including geo-verification, perceptual image hashing, and timestamp checks. Additionally, an audio analysis module processes fire alarm recordings using signal processing and machine learning techniques such as RMS energy for loudness detection, RT60 for reverberation analysis, and MFCC with cosine similarity for sound matching. All collected data is securely stored in a database and displayed on an administrative dashboard, enabling authorities to review inspection results and make informed decisions. The system is tested for accuracy, reliability, and real-time performance, demonstrating improved transparency and efficiency compared to conventional inspection methods.

4. SYSTEM ARCHITECTURE

The SmartInspect AI system is designed using a distributed client-server architecture that integrates mobile-based data acquisition, backend processing, and AI-driven microservices. The architecture ensures secure, real-time, and multi-layer verification of fire safety inspections. The overall workflow is organized into six major stages as follows:

Step 1: Inspector Authentication and Inspection Initialization

The process begins with secure authentication of the inspection officer through the mobile application. Only authorized users can initiate inspection tasks, ensuring system integrity. Once logged in, the application activates device-level services such as GPS and sensors to capture real-time environmental data. The system fetches assigned inspection details, including building information and floor-wise tasks, from the backend server. This step ensures that the inspection process starts with verified personnel and correct contextual data.

Step 2: Multi-Modal Data Acquisition at Inspection Site

During on-site inspection, the mobile application (developed using Flutter) captures multiple forms of data to establish authenticity. This includes geo-tagged images

of fire safety equipment, audio recordings of fire alarms, timestamps for activity tracking, and barometric pressure readings to determine floor level. The use of multiple sensors ensures that each inspection is validated across location, time, and spatial dimensions. This multi-modal data collection eliminates reliance on a single source of verification and strengthens the credibility of inspection evidence.

Step 3: Secure Data Transmission and Backend Processing

All captured data is transmitted securely to the backend server using REST APIs. The backend, developed using Node.js and Express, handles request processing, validation, and storage. Data such as images and audio files are sent using Axios and FormData to ensure efficient file transfer. The backend performs preliminary checks, including timestamp validation and data completeness, before storing the information in a database such as MongoDB or Firebase. This step ensures reliable data management and prepares the data for advanced analysis.

Step 4: Pre-Processing and Validation of Audio Data

For fire alarm verification, the uploaded audio file undergoes an initial filtering stage. The system checks whether the dominant frequency of the signal exceeds 20 Hz to eliminate invalid inputs such as silence or background noise. If the audio passes this threshold, it is forwarded to a Python-based microservice hosted on Render via an API endpoint (/analyze). Before analysis, the audio format is converted from WebM to WAV using FFmpeg to ensure compatibility with signal processing libraries. This step acts as a gatekeeper, ensuring that only meaningful audio data is processed further.

Step 5: AI-Based Audio Analysis and Verification

The core intelligence of the system lies in the audio analysis module implemented using Flask and Librosa. The microservice performs multiple levels of validation:

Loudness Detection: The system calculates Root Mean Square (RMS) energy to determine whether the sound is sufficiently loud, as fire alarms are expected to produce high-intensity signals.

Reverberation Analysis: Using RT60 estimation, the system evaluates the presence of echo, which indicates that the sound originates from a real indoor environment rather than a pre-recorded or manipulated source.

Audio Fingerprint Matching: The system extracts Mel-Frequency Cepstral Coefficients (MFCCs) to generate a unique representation of the sound signal. This fingerprint is compared with a reference fire alarm using Cosine

Similarity. If the similarity score exceeds 0.85, the sound is classified as a valid fire alarm.

This multi-stage AI validation ensures high accuracy and prevents false verification.

Step 6: Result Aggregation, Dashboard Visualization, and Decision Making

After analysis, the results are sent back to the backend server and integrated into a structured inspection report. The system aggregates all validation outputs, including image verification, geo-location confirmation, floor detection, and audio analysis. These results are displayed on a web-based admin dashboard, where authorities can review detailed evidence and system-generated insights. Based on this information, the final decision to approve or reject the Fire NOC is made. This step completes the workflow by ensuring transparency, accountability, and efficient decision-making

Decision: The generated NOC Summary is presented to a senior officer or decision-making authority. They review the evidence and the AI's remarks and make a final Decision to either Approve or Reject the NOC. Report Issuance: Based on this final decision, the system automatically issues either an NOC Approved Report or an NOC Rejected Report, completing the workflow.

time. The integration of barometric sensors enabled accurate floor-level detection, which helped confirm that inspections were conducted across all required levels of a building. This addressed a major limitation of conventional inspection systems, where floor-wise verification is often missing.

The image validation module, based on perceptual hashing, effectively detected duplicate or reused images, reducing the possibility of data tampering. This ensured that each captured image represented genuine inspection evidence. Additionally, the system's ability to store metadata alongside images further strengthened data integrity and traceability. A key highlight of the system is the audio-based fire alarm verification module, which demonstrated reliable performance in distinguishing valid fire alarm sounds from noise or invalid inputs. The combination of RMS energy for loudness detection, RT60 for reverberation analysis, and MFCC-based cosine similarity for pattern matching provided a robust multi-stage validation process. Experimental testing showed that the system could accurately identify functional fire alarms when all validation conditions were satisfied, while correctly rejecting weak, silent, or mismatched audio signals.

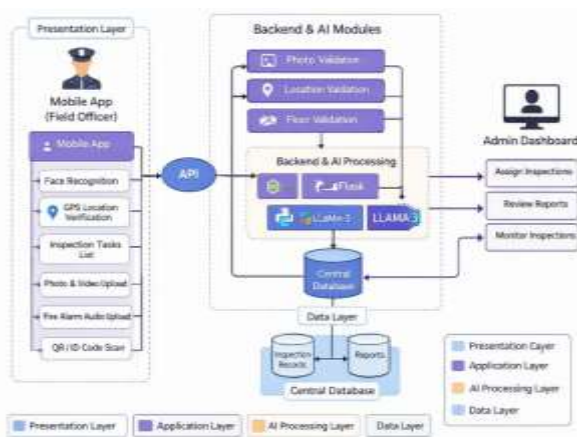


Fig 1. Architecture of the system

5.RESULTS AND DISCUSSION

The SmartInspect AI system was evaluated based on its ability to improve the reliability, transparency, and efficiency of fire safety inspections compared to traditional manual methods. The implementation of multi-layer verification techniques demonstrated significant improvements in ensuring the authenticity of inspection data. The system successfully validated inspection activities using geo-tagging and timestamp mechanisms, ensuring that data was captured at the correct location and

From a usability perspective, the mobile application provided a smooth and efficient interface for inspectors, enabling real-time data capture without adding complexity to the workflow. The backend system ensured fast data processing and secure storage, while the admin dashboard allowed authorities to review inspection reports in a structured and user-friendly manner. This significantly reduced the time required for NOC approval and improved decision-making efficiency. Overall, the results indicate that the SmartInspect AI system enhances inspection accuracy, minimizes human errors, and reduces the risk of fraudulent reporting. The integration of AI and sensor-based validation creates a more reliable and transparent inspection process, making it a practical solution for modern fire safety compliance systems.

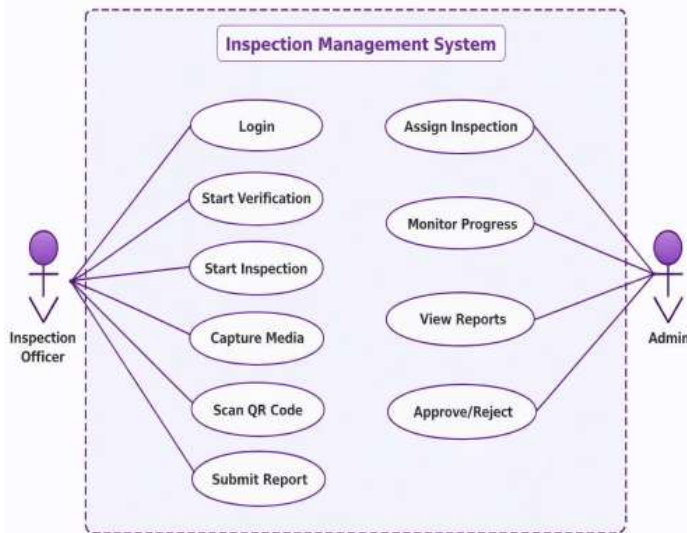


Fig 1. Use case Diagram

6. CONCLUSION

The SmartInspect AI system presents an effective solution to overcome the limitations of traditional fire safety inspection methods, which are often manual, time-consuming, and prone to errors or manipulation. By integrating advanced technologies such as geo-tagging, barometric floor detection, perceptual image hashing, and AI-based audio analysis, the system ensures that inspection data is authentic, verifiable, and tamper-resistant. The use of a mobile application for real-time data collection, combined with a centralized backend and intelligent validation mechanisms, significantly improves the overall efficiency and reliability of the Fire NOC process.

Furthermore, the system introduces a multi-layer verification approach that enhances transparency and accountability in inspection workflows. The inclusion of automated analysis and structured reporting reduces the burden on authorities while enabling faster and more informed decision-making. With its scalable architecture and cost-effective implementation, SmartInspect AI has the potential to be adopted in real-world scenarios, contributing to safer infrastructure and more efficient governance in urban environments. Ultimately, this project is about one simple goal: using smart technology to keep our families, friends, and communities safe. It's a big step forward in building a safer, more secure future for everyone.

7. ACKNOWLEDGEMENT

The authors would like to express their sincere appreciation to their project guide, **Prof. Pranali Bhusare**, for her constant guidance, encouragement, and valuable suggestions throughout the development of this project. Her insightful feedback and support played a vital role in refining the concepts and ensuring the successful completion of this research work.

We also extend our gratitude to the Department of Computer Engineering, Atharva College of Engineering, for providing the necessary resources, technical support, and a conducive environment for carrying out this project. The continuous assistance and constructive inputs from faculty members significantly contributed to improving the quality and direction of our work.

8. REFERENCES

- [1] A. Krizhevsky, I. Sutskever, and G. E. Hinton, "ImageNet Classification with Deep Convolutional Neural Networks," in *Advances in Neural Information Processing Systems*, 2012.
- [2] T. Giannakopoulos and A. Pikrakis, *Introduction to Audio Analysis: A MATLAB Approach*, Academic Press, 2014.
- [3] S. Madakam, R. Ramaswamy, and S. Tripathi, "Internet of Things (IoT): A Literature Review," *Journal of Computer and Communications*, vol. 3, no. 5, pp. 164–173, 2015.
- [4] B. McFee et al., "Librosa: Audio and Music Signal Analysis in Python," in *Proceedings of the 14th Python in Science Conference*, 2015.
- [5] K. He, X. Zhang, S. Ren, and J. Sun, "Deep Residual Learning for Image Recognition," in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*, 2016.
- [6] S. Ricken, L. Barkhuus, and Q. Jones, "Going Online to Meet Offline: Organizational Practices of Social Activities through Meetup," June 2017.
- [7] J. Redmon and A. Farhadi, "YOLOv3: An Incremental Improvement," *arXiv preprint arXiv:1804.02767*, 2018.

[8] J. Zhao and G. Zhou, "Social Media Use and Loneliness among Young Adults: The Mediating Role of Social Interaction Quality," 2020.

[9] D. Zhang, H. Wang, and B. Li, "Smart Fire Detection System using Internet of Things (IoT)," in *IEEE International Conference on Smart Computing*, 2020.

[10] O. Zell, J. Pálsson, and K. Hernandez-Diaz, "Image-Based Fire Detection in Industrial Environments with YOLOv4," 2022.

[11] H. Sun, N. Wang, J. Jia, H. Huang, H. Xiong, and L. He, "Platform-Oriented Event Time Allocation," May 2022.

[12] J. Wen, P. Li, and J. Chu, "Scene Matching for Indoor Location Verification," in *Advances in Computer Science and Ubiquitous Computing*, Singapore: Springer, 2022, pp. 119–125.

[13] K. C. P. Wang, Q. Li, and W. L. Gong, "Mobile App for Smart Inspections in Civil Engineering," *Procedia Engineering*, vol. 269, pp. 888–895, 2022.

[14] Priyadarshini College of Engineering, "Fire Detection and Alert System using AI," *IRJET*, 2022.

[15] A. Alayed, R. Alidrisi, E. Feras, S. Aboukazzana, and A. Alomayri, "Real-Time Inspection of Fire Safety Equipment using Computer Vision and Deep Learning," *Engineering, Technology & Applied Science Research*, 2024.

[16] F. Lin, "Efficient Visual Inspection of Fire Safety Equipment in Buildings," *ScienceDirect*, 2025

[17] S. J. Lee, H. S. Yun, Y. B. Sim, and S. H. Lee, "Design and Validation of an Edge-AI Fire Safety System with SmartThings Integration," *Applied Sciences*, 2025.

[18] V. Loboichenko, "Review of Advances in Fire Extinguishing Based on Computer Vision Applications," 2025.

[19] L. Kratochvila et al., "Automatic Smoke Detector Inspection using Deep Learning Models," 2026.

[20] M. Müller, "Librosa: Audio and Music Signal Analysis in Python," 2026