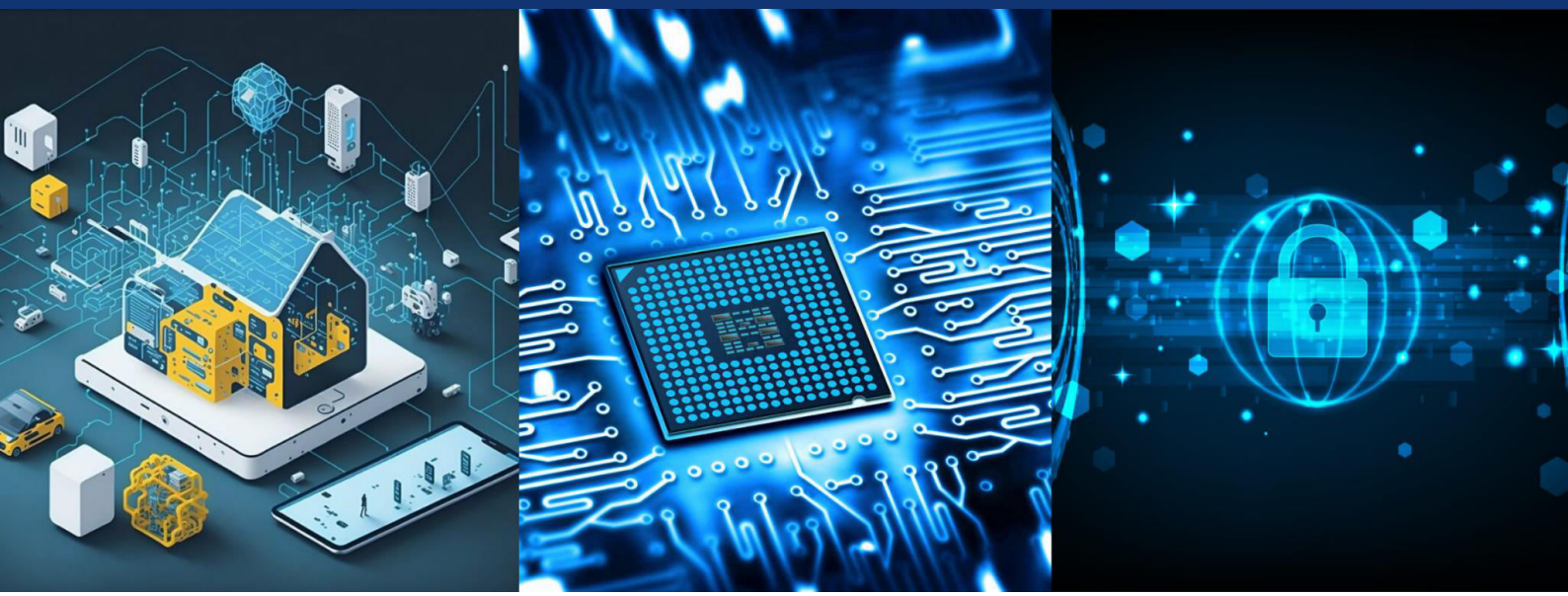
IJIRCCE

ISSN(O): 2320-9801

ISSN(P): 2320-9798



International Journal of Innovative Research in Computer and Communication Engineering

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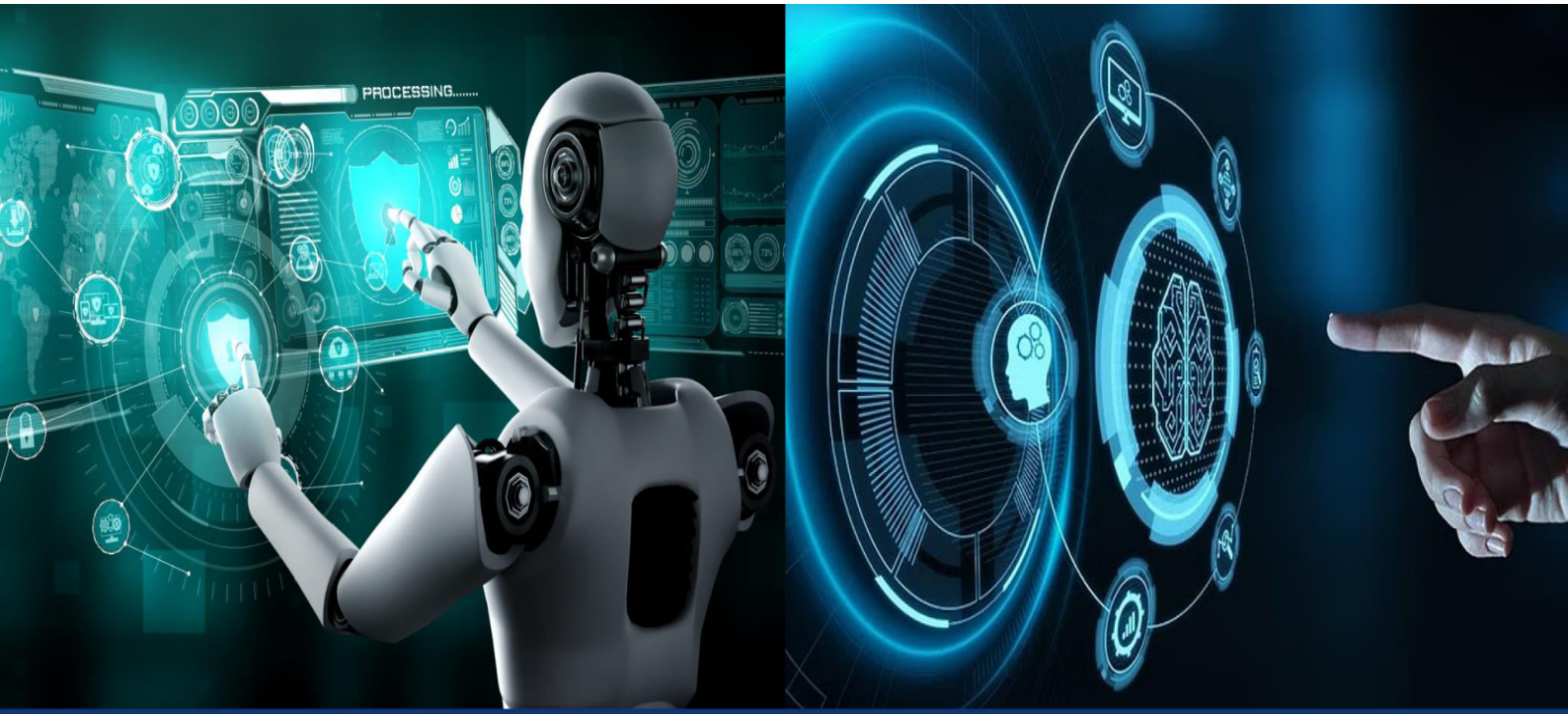

Impact Factor: 9.927

Volume 14, Issue 5, May 2026

© 2026 IJIRCCE | Volume 14, Issue 5, May 2026 DOI: 10.15680/IJIRCCE.2026.1405050

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 9.927| ESTD Year: 2013|

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

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Crowd Guard AI: Predictive Crowd Safety Intelligence System

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ABSTRACT: Given the quick increase in urban populations and large-scale public gatherings, ensuring crowd safety has become a critical challenge. Incidents such as overcrowding, stampedes, and panic situations often arise as a result of the absence of real-time monitoring and predictive analysis in traditional surveillance systems. Existing methods mainly rely on manual observation of CCTV footage, which is inefficient, error-prone, and incapable of providing early warnings.

This project, Crowd Guard AI: Predictive Crowd Safety Intelligence System, proposes an advanced AI-powered system that incorporates computer vision, deep learning, and real-time analytics to enhance crowd monitoring and safety. The system utilizes state-of-the-art models such as YOLO for human detection and Deep SORT for multi-object tracking across multiple camera feeds. It further incorporates machine learning techniques to analyse crowd density, detect abnormal movement patterns, and identify panic behaviour in real time.

Additionally, the system generates dynamic crowd density heatmaps and provides predictive insights to foresee possible dangers before they become more serious. A Flask-based web dashboard is developed to visualize crowd conditions, track individuals, and deliver instant alerts to authorities. This enables faster decision-making and proactive crowd control measures.

I. INTRODUCTION

The rapid growth of urban populations and the increasing frequency of large public gatherings such as festivals, concerts, sports events, and religious ceremonies have made crowd management a critical concern in modern society. Effective crowd management is crucial for maintaining public safety and averting hazardous circumstances including panic attacks, overcrowding, and stampedes. The shortcomings of current crowd monitoring systems have been brought to light by a number of fatal incidents in recent years, underscoring the need for more clever and proactive solutions.

Traditional crowd management approaches primarily rely on surveillance cameras monitored by human operators. Although CCTV systems provide continuous visual coverage, they lack the capability to automatically analyse crowd behaviour and detect potential risks in real time. Human monitoring is often limited by fatigue, delayed reaction times, and the inability to process multiple video feeds simultaneously. As a result, authorities typically respond to emergencies only after problems have already gotten worse, which raises the possibility of fatalities and injuries.

New opportunities for creating intelligent surveillance have been made possible by developments in artificial intelligence, computer vision, and machine learning. systems capable of understanding and predicting human behaviour. These technologies enable automated detection, tracking, and analysis of individuals within a crowd, allowing for real-time insights into crowd density, movement patterns, and behavioural anomalies. By leveraging these capabilities, it is possible to transition from reactive crowd management to proactive and predictive safety systems.

This project introduces Crowd Guard AI: Predictive Crowd Safety Intelligence System, an innovative solution designed to enhance crowd monitoring using AI-driven techniques. Deep learning models are integrated into the system such as YOLO for real-time human detection and Deep SORT for accurate multi-object tracking across video frames. By analysing movement patterns and crowd density, the system can identify unusual behaviours such as sudden crowd surges, congestion, and panic movements.

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In addition to real-time monitoring, the proposed system incorporates predictive analytics to forecast potential risks before they occur. It creates dynamic heatmaps of crowd density and employs machine learning algorithms to find anomalous patterns that can point to dangerous situations. A Flask-based web dashboard that offers authorities real-time visualization, alarms, and decision support tools complements the system.

II. SYSTEM MODEL AND ASSUMPTIONS

The proposed Crowd Guard AI: Predictive Crowd Safety Intelligence System is designed as a real-time framework for multi-camera surveillance that combines machine learning and computer vision methods for intelligent crowd monitoring. Multiple CCTV cameras placed across a monitored area, such as stadiums, train stations, or public meetings supply the system with real-time video streams.

YOLO and other deep learning models are used to process these video inputs for human detection and Deep SORT for tracking individual movement across frames. The system then analyses spatial and temporal features such as crowd density, velocity, and direction of movement to understand crowd behaviour. A centralized processing unit performs prediction and anomaly detection, while a Flask-based dashboard displays real-time analytics, heatmaps, and alerts for decision-making.

The system operates under several key assumptions to ensure accurate and efficient performance. It assumes that the surveillance cameras are properly installed with adequate coverage of the target area and minimal blind spots. The video input is expected to have sufficient resolution and stable lighting conditions to allow reliable detection and tracking of individuals. It is also assumed that the crowd movement follows observable patterns, enabling machine learning models to identify deviations such as sudden congestion or panic behaviour. Additionally, the system presumes the availability of computational resources capable of processing video streams in real time without significant latency.

Furthermore, the model assumes that environmental conditions such as weather, occlusion, and extreme lighting variations are within manageable limits and do not severely affect detection accuracy. It also assumes that the training data used for machine learning models is diverse enough to generalize across different crowd scenarios and environments. The system relies on continuous data flow for effective prediction, meaning interruptions in video streams may impact performance. Despite these assumptions, the design is flexible and scalable, allowing integration with advanced sensors, cloud computing, and edge devices in future enhancements to improve robustness and reliability.

III. EFFICIENT COMMUNICATION

Efficient communication is a critical component of the Crowd Guard AI: Predictive Crowd Safety Intelligence System, as it ensures timely delivery of information between system components and authorities responsible for crowd management. The system's real-time data processing and transmission capabilities allow for prompt decision-making in urgent circumstances. A centralized or edge-based processing unit receives video data from several security cameras and uses AI models to analyse it. Lightweight communication protocols and streamlined data pipelines are employed to reduce latency, guaranteeing that only pertinent data, such warnings are, crowd density metrics, and abnormal behaviour indicators are transmitted rather than raw video data.

The system utilizes efficient communication frameworks such as REST APIs and Web Sockets to enable seamless interaction between the backend and the frontend dashboard. Real-time updates, including crowd density heatmaps, tracking information, and alert notifications, are instantly reflected on the dashboard. In high-risk situations, automated alerts can be sent to authorities through multiple channels such as SMS, email, or mobile notifications. This multi-channel communication approach ensures that critical warnings reach the concerned personnel without delay, even in cases where one communication medium fails.

Additionally, the system is designed to support scalability and distributed communication through edge computing and cloud integration. By processing data closer to the source (edge devices), the system reduces bandwidth usage and improves response time. Communication between different modules is secured using encryption protocols to ensure data privacy and integrity. Overall, efficient communication in Crowd Guard AI enhances responsiveness, reduces system overload, and ensures reliable transmission of critical information, thereby improving the effectiveness of crowd safety management.

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IV. SECURITY

Security is a crucial aspect of the Crowd Guard AI: Predictive Crowd Safety Intelligence System, as it deals with sensitive surveillance data and real-time monitoring of public spaces. The system is designed to ensure data confidentiality, integrity, and availability throughout its operation. All video streams and Encrypted communication technologies like HTTPS and secure WebSocket connections are used to safely transfer processed data. This stops data from being tampered with, intercepted, or accessed by unauthorized parties. Additionally, only authorized individuals, such as administrators and security authorities, are able to view or manage the system dashboard thanks to authentication and role-based authorization.

To further enhance security, the system incorporates data protection mechanisms such as secure storage and anonymization techniques. Sensitive information, including video recordings and user data, is stored in protected databases with proper encryption. Wherever possible, personal identities are not explicitly stored, and the system focuses on analysing crowd patterns rather than individual identification, thereby maintaining privacy compliance. Regular logging and monitoring mechanisms are implemented to track system activities, detect suspicious behaviour, and prevent misuse of the platform.

Moreover, the system is designed to be resilient against cyber threats and system failures. Techniques such as firewall protection, intrusion detection systems, and periodic security updates are employed to safeguard the infrastructure. Backup mechanisms and failover strategies ensure system availability even during technical failures or attacks. As the system can be integrated with cloud and edge computing environments, secure APIs and token-based authentication methods are used to protect communication between distributed components. Overall, the security framework of Crowd Guard AI ensures safe, reliable, and privacy-aware operation, which is essential for large-scale deployment in real-world crowd monitoring scenarios.

V. RESULT AND DISCUSSION

The Crowd Guard AI: Predictive Crowd Safety Intelligence System demonstrated effective performance in real-time crowd monitoring and analysis. The system successfully detected individuals, tracked their movement across frames, and accurately estimated crowd density under different scenarios. It was able to identify abnormal behaviours such as sudden crowd congestion and panic-like movements, generating timely alerts for authorities. The dashboard provided clear visualization through heatmaps and live tracking, enabling quick understanding of crowd conditions. Overall, the system achieved low latency, high detection accuracy, and reliable alert generation, proving its capability to enhance crowd safety and support proactive decision-making in large public environments

VI. CONCLUSION

The Crowd Guard AI: Predictive Crowd Safety Intelligence System presents an intelligent and efficient approach to modern crowd that rely on manual monitoring, this system enables automated detection, tracking, and analysis of crowd behaviour. By integrating models such as YOLO and Deep SORT, the system can accurately estimate crowd density, monitor movement patterns, and identify abnormal or panic situations. The inclusion of a real-time dashboard and alert mechanism further enhances its practicality, allowing authorities to respond quickly and effectively to potential risks.

Overall, the proposed system shifts crowd management from a reactive to a proactive approach, significantly improving public safety and reducing the chances of accidents such as stampedes. Its scalability and adaptability make it suitable for deployment in various environments, including smart cities, transportation hubs, and large public events.

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