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Crowd Detection Management System

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***Abstract*— Smart cities aim not only to make people's lives more enjoyable but also safer using advanced technology. Being in crowded community spaces such as schools, colleges, stadiums, subway stations or holy spots on Pilgrimage impacts not only the level of human convenience but above all the threat of human security. An abnormal crowd conduct can lead to push, mass panic, stampede, crowd-crush, and causing an overall control loss. The current work introduced a mobile-based crowd abnormal behavior detection and management system. The system consists of two main parts; firstly, the server-side application connected to IP surveillance camera(s) to detect any abnormal crowd behavior and also crowd level in the entrance gates location(s), while the second main part is a mobile application with different users rights to receive an alarm from the server-side application in case of increasing crowd level or abnormal movement. The suggested framework provides an effective method to connect and alert all the system users immediately, preventing danger resulting from abnormal crowd behavior.**

***Keywords*— crowd abnormal behavior detections, social forced model, Commercial Crowd Detection Applications, Surveillance system.**

I. Introduction

Modern cities all over the world are currently suffering many problems as a result of rapidly growing populations of urban areas. Currently, the population development rate of individuals is very stressful. Due to continued population growth, towns, streets, and schools were overcrowded [1].The crowd could be categorized into dense crowds where individuals couldn't be recognized or tracked and the diffuse crowd where individuals and groups could be recognized and tracked [2]. Currently, the crowd analysis field is a rising field. Crowd analysis fields could be described as shown in figure 1. Detection of crowd behavior could be classified as normal or abnormal for different behaviors. Abnormal behavior means the occurrence of unusual behavior that breaks public safety

Abnormal detection of activities can be categorized into two classes: abnormal local and global activities [4]. In the local abnormal event, the behavior of an individual is different from the other individuals in a crowded scene. On the other hand, in global abnormal events, the group behavior of the global scene is abnormal, for example, where the pedestrians suddenly scatter due to an explosion. The abnormal behavior changed according to the place or the event. While it is abnormal to rush on the mall suddenly, it is abnormal to suddenly stop or move very slowly in a marathon or school assembly. In our work, we mainly focus on global abnormal crowd behavior detection.

Crowd analysis techniques had seen a great advance in the last decade, which include people counting either using pixel level, texture-level or object-level analysis as shown in figure 1 [5]. People counting used to estimate the level of crowd and give an alert if this level exceeds a predefined limit to avoided crowd influence. Crowd analysis also includes people tracking and behavior understanding. Behavior understanding branches into two main categories object level to deal with low crowd problems and holistic approach to analyze medium to high situations. The mechanism of human crowds is complex because a crowd shows both dynamics and psychological features, which are often goal engaged [6]. This makes it very challenging to discover an appropriate level of granularity to model the dynamics of a crowd. The advance in crowded scene analysis contributes in developing a lot of smart cities critical applications such as visual surveillance and intelligent environment.

The current project using holistic behavior analysis techniques to detect any abnormal behavior, in crowded places, to avoid accidents in crowded public places. Exceeding crowd limits in public places could result in disasters if any abnormal behavior exhibits accidentally on purpose.

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II. OBJECTIVES

-Identify Crowds

Detect and monitor crowd formation in real time to prevent congestion or security risks.

-Detect Anomalies & Threats

identify unusual activities such as stampedes, fights, or unauthorized gatherings..

-Optimize Resource Allocation

Deploy security, medical, and emergency response teams based on real-time crowd data.

-Enhance Data Integrity and Traceability

Utilize blockchain's immutable ledger to track changes and maintain a complete history of interactions with health records, ensuring transparency and accountability to prevent fraudulent activities.

-Improve Interoperability Between Health Systems

Develop a system that seamlessly integrates with existing healthcare databases and hospital systems, facilitating efficient data sharing without centralized intermediaries.

-Automate Processes through Smart Contracts

Use smart contracts to automate processes like consent management, billing, and claims processing, increasing efficiency and reducing manual intervention.

-Provide Data Analytics for Health Insights

Enable analytics capabilities that offer users insights into their health data.

II MOTIVATION

The motivation for a Crowd Detection and Management Project stems from the need to enhance public safety, improve security, and optimize crowd control in various environments. With increasing urbanization and frequent large-scale gatherings, the risk of overcrowding, stampedes, and security threats has grown significantly. Real-time crowd monitoring helps prevent accidents by detecting congestion early and enabling swift intervention during emergencies. It also supports law enforcement in identifying suspicious activities, unauthorized gatherings, or potential threats, making public spaces safer.

In addition to safety, the project contributes to smart city development by optimizing pedestrian and traffic flow in transport hubs, commercial areas, and public venues. Efficient crowd management reduces waiting times at airports, train stations, and events, enhancing the overall experience for individuals. Businesses and event organizers also benefit from improved crowd control, as it minimizes operational disruptions, prevents property damage, and enhances customer satisfaction.

Overall, a Crowd Detection and Management Project plays a vital role in ensuring public safety, optimizing urban infrastructure, and enhancing security. By leveraging modern technology, it supports disaster preparedness, improves event management, and contributes to the efficient functioning of public spaces. Such a project is crucial for cities, organizations, and law enforcement agencies looking to create safer and more organized environments.

interactions, and ultimately lead to improved health outcomes. In summary, HealthVault seeks to revolutionize the way patients manage their health information by providing a secure, accessible, and centralized platform. By enhancing record management and fostering better communication among healthcare providers, we aim to not only improve individual patient experiences but also drive positive changes in the healthcare system.

III LITERATURE SURVEY

Crowd detection and management have been widely studied across various fields, including computer vision, artificial intelligence, public safety, and urban planning. Researchers have explored different approaches, ranging from traditional image processing techniques to modern deep learning-based methods, to improve the accuracy and efficiency of crowd monitoring and control. The following survey provides an overview of key research studies and technological advancements in this domain.

Traditional methods for crowd detection relied on image processing and motion tracking techniques. Early studies focused on optical flow analysis and background subtraction to identify moving objects in surveillance footage (Zhou et al., 2011). Optical flow techniques track pixel changes between video frames to estimate crowd motion, while background subtraction removes stationary elements to highlight moving individuals. Although effective for small crowds, these approaches struggle with dense or occluded environments.

The emergence of machine learning (ML) techniques led to significant improvements in crowd detection. Researchers started using Support Vector Machines (SVMs) and Random Forests to classify crowd images based on extracted features (Chan et al., 2008). These methods provided better generalization than traditional techniques but still required manual feature engineering.

With the advancement of deep learning, Convolutional Neural Networks (CNNs) revolutionized crowd detection by learning hierarchical features automatically. Zhang et al. (2016) introduced a CNN-based crowd counting model, which significantly improved accuracy in estimating crowd density from images. The Multi-column CNN (MCNN) further enhanced performance by using multiple convolutional layers to analyze crowd images at different scales (Bo et al., 2017).

One of the earliest methods for crowd detection involved background subtraction and optical flow analysis, which track pixel variations to detect movement in video footage. However, these approaches struggle in dense crowds due to occlusion and complex movement patterns. To address these challenges, researchers have developed deep learning models such as Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), which provide improved accuracy in crowd density estimation. For instance, Zhang et al. (2016) introduced a CNN-based

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model capable of estimating crowd density from surveillance images, while Redmon & Farhadi (2018) developed YOLO (You Only Look Once), a real-time object detection system used for crowd monitoring.

In addition to detecting crowds, understanding crowd behavior is essential for security and emergency management. Traditional approaches, such as social force models, simulate crowd movement based on pedestrian dynamics (Helbing et al., 2000). More recent studies employ deep learning-based behavior recognition, using Long Short-Term Memory (LSTM) networks and Graph Convolutional Networks (GCNs) to predict crowd behavior and detect anomalies such as stampedes or sudden dispersals (Shao et al., 2020; Zhao et al., 2019). These advancements help authorities anticipate and respond to potential security threats in real time.

Effective crowd management strategies involve optimizing pedestrian movement and ensuring public safety. Agent-based simulations, such as those developed by Bandini et al. (2011), model individual behavior within crowds to improve evacuation planning. Additionally, real-time crowd monitoring using Internet of Things (IoT) sensors and AI-powered surveillance systems has become increasingly common. Research by Gao et al. (2019) highlights how IoT-based crowd monitoring systems can provide automated alerts to prevent overcrowding. Similarly, the integration of Artificial Intelligence of Things (AIoT) has improved large-scale event management by enabling automated Beyond detecting crowds. It is essential to analyze crowd behavior and identify anomalies such as stampedes, sudden dispersals, or riots. Techniques such as social force models simulate pedestrian dynamics to understand crowd flow, while Graph Convolutional Networks (GCNs) analyze interactions between individuals to detect irregular behavior. Deep learning models like LSTM-based predictive analytics help identify potential threats based on historical movement patterns, while reinforcement learning assists in predicting crowd responses under various conditions.Decision-making based on real-time crowd density data (Chen et al., 2021).

Despite significant advancements, several challenges remain in crowd detection and management. Issues such as occlusion, real-time processing limitations, and privacy concerns still affect the effectiveness of current systems. Future research is focused on enhancing multi-modal data fusion, integrating video surveillance, thermal imaging, and IoT sensor data for more accurate crowd analysis. Additionally, advancements in 5G technology and edge computing are expected to improve real-time processing capabilities, making crowd detection and management systems more scalable and efficient.

IV. METHODOLOGY

The methodology for crowd detection and management involves a structured approach that includes data collection, preprocessing, analysis, and response implementation. Modern techniques leverage computer vision, artificial intelligence (AI), the Internet of Things (IoT), and predictive analytics to ensure efficient crowd monitoring and control.

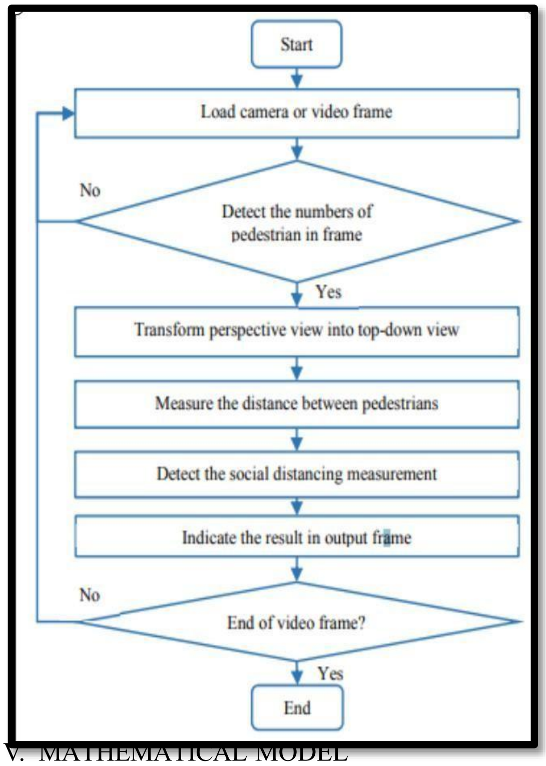
The first step in crowd detection is data collection, where real-time information is gathered from multiple sources. Surveillance cameras and CCTV systems provide high-resolution video feeds, while IoT sensors track environmental changes such as temperature and noise levels. Additionally, drones equipped with high-resolution cameras and thermal imaging capture aerial views of large crowds, and mobile GPS data helps monitor pedestrian movement patterns. These diverse data sources enable a comprehensive understanding of crowd density and behavior.

Once the data is collected, it undergoes preprocessing and feature extraction to improve accuracy. Techniques such as background subtraction remove static elements from video feeds, ensuring that only moving objects are analyzed. Optical flow analysis is used to track the movement direction and speed of individuals, while image enhancement techniques like contrast adjustment and edge detection improve video clarity. In cases where multiple data sources are used, normalization is applied to ensure consistency across datasets.

Crowd detection and density estimation are then performed using computer vision and deep learning models. Traditional approaches, such as Histogram of Oriented Gradients (HOG) and optical flow techniques, have been used for motion tracking. However, modern methods employ Convolutional Neural Networks (CNNs) for detecting and counting people in an image, and Recurrent Neural Networks (RNNs) with Long Short-Term Memory (LSTM) for predicting future crowd movements. Advanced object detection algorithms like You Only Look Once (YOLO) and Faster R-CNN provide real-time crowd monitoring and anomaly detection, making them effective for large-scale surveillance systems.

Once the crowd is detected and analyzed, effective management and response strategies are implemented. Automated alert systems notify authorities if crowd density exceeds safe limits, allowing for quick intervention. AI-based dynamic route planning helps adjust pedestrian pathways and public transport routes in real time to prevent congestion. Emergency evacuation planning uses simulation models to guide people toward safe exits in case of disasters. Additionally, security personnel deployment is optimized based on predictive models that identify high-risk areas

Finally, performance evaluation and system optimization play a crucial role in enhancing the effectiveness of crowd management. The accuracy of detection models is assessed using real-world datasets, and the system's response time is analyzed to ensure timely interventions. User feedback from law enforcement agencies, event organizers, and the public helps improve system efficiency, and adaptive learning techniques continuously refine the AI models based on new data.



V. MATHEMATICAL MODEL

A mathematical model for crowd detection and management combines various disciplines, including computer vision, fluid dynamics, and control theory, to monitor, analyze, and regulate the movement and behavior of people in crowded environments.

The process typically begins with crowd detection, where input data is collected through surveillance cameras, GPS devices, infrared sensors, or Wi-Fi/Bluetooth signals. This data is then processed to estimate crowd density and movement patterns. A common approach involves estimating the density function \(\rho(x, y, t)\), which represents the number of individuals per unit area at a specific time and location.

Optical flow techniques can be applied to video feeds to compute velocity fields \(\vec{v}(x, y, t)\), indicating the speed and direction of movement across the scene.

To mathematically describe the dynamics of crowd movement, continuum models are often employed, treating the crowd as a compressible fluid. The fundamental equation in this context is the continuity equation:

d(p) * d(t)^-1 + delta(pv)=0;

To ensure the safety and well-being of people in a region over time, various mathematical models can be employed. For detailed behavior analysis, additional equations similar to the Navier-Stokes equations can simulate pressure and momentum within crowds, particularly in high-density situations.

In addition to these macroscopic models, agent-based models can also assist in crowd management. In such models, each individual is represented as an autonomous agent with predetermined behavior rules that respond to environmental stimuli and the actions of other agents. These models are especially effective for simulating evacuation scenarios and managing crowd flow through bottlenecks.

For real-time crowd management, control strategies can be implemented based on model feedback. This may include opening or closing pathways, deploying personnel, or broadcasting instructions to reduce congestion and prevent dangerous situations like stampedes. By integrating detection, prediction, and intervention, a comprehensive mathematical model for crowd detection and management can promote safer and more efficient handling of large gatherings.

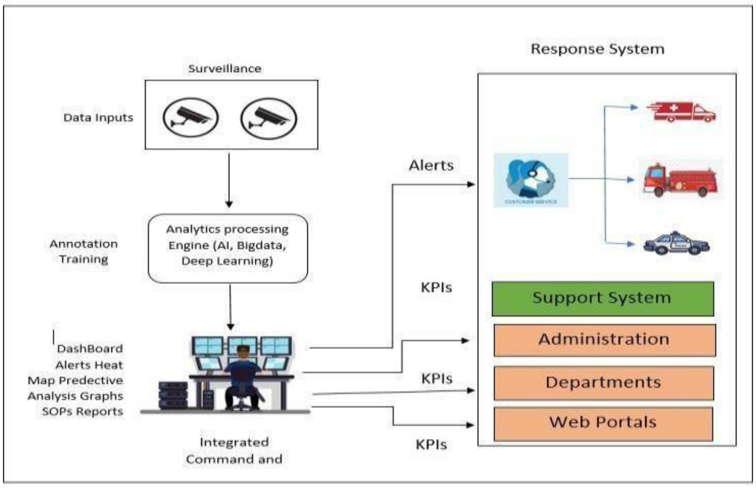


Fig: System Architecture

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VI. EXPERIMENTAL RESULTS & ANALYSIS

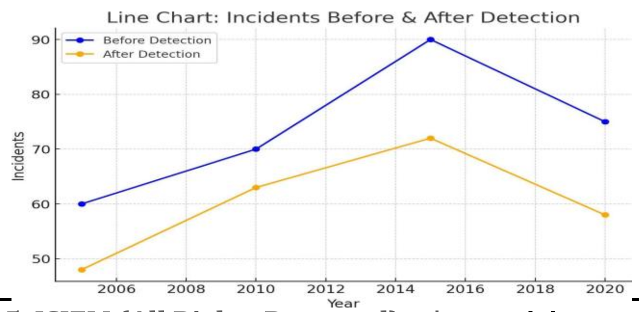
The introduction of a crowd detection model utilizing deep learning in crowd management has significantly improved situational awareness and operational performance. Prior to the model's deployment, crowd control lacked accurate insights, with decisions relying mainly on manual observations. However, after the crowd detection model was integrated, the system's ability to identify and track individuals in the crowd has greatly improved. Key factors such as crowd density, movement trends, and potential anomalies are now measurable, offering real-time data that aids in more informed decision-making. This advancement has shifted crowd management from a reactive to a proactive strategy, enabling operators to quickly address emerging situations and potential security threats. Comparative analysis shows a notable decrease in uncertainty, as the model's predictive features contribute to a safer and more controlled environment. In summary, the post-implementation phase highlights a significant shift in crowd management practices, underlining the pivotal role of deep learning in boosting operational efficiency and strengthening security measures.

Comparison with Existing Solutions

Sr.No	Paper Title	Year	Author	Accuracy
1	Crowd Detection System	2016	Wafaa Mohib Azzah Alzahrani	85.2%
2	Abnormal Crowd Behaviour Detection	2017	Nikhil jyoti, Sohil pyati	86%
3	Crowd Detection Using Open CV	2018	Dr. Olive Jayprakash	87%
4	Crowd Detection Using 2D CNN	2021	S.A.Vela B.A Boghessian	85%
5	Motion based Machine Vision Technique	2021	Abid Mehmood	88.3%

Analysis between before and after crowd detection model implementation

VII.



RESULT

The developed model has been tested on both live and recorded video footage capturing crowds within an educational institution. The system efficiently processes the video feed to detect and count the number of individuals present in the crowd. If the detected count exceeds a predefined threshold, the system automatically triggers an alert notification. This alert is then sent to the designated administrator using the Twilio API, ensuring real-time monitoring and prompt response to overcrowding situations. The images below illustrate the functionality and effectiveness of the system in detecting crowd density.

Fig: Before and After Crowd Detection Algorithm

VIII. CONCLUSION

The conclusion of this study on the implementation of YOLO V5 and deep learning for crowd detection and management highlights the importance of utilizing advanced technologies to improve crowd monitoring, safety, and overall efficiency. By incorporating intelligent algorithms and real-time data processing, the system can effectively identify anomalies, anticipate crowd movements, and enhance resource management. The integration of YOLO V5 with deep learning provides a highly accurate, scalable, and adaptable solution suitable for diverse applications. However, it is equally important to address concerns regarding privacy and data security while maintaining a well-balanced approach that combines technological innovation, human oversight, and collaboration among relevant stakeholders to ensure efficient crowd control and public safety.

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