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# Drone-Based Real-Time Crowd Density Estimation Using Deep Learning Techniques

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**Abstract:** Crowd management is really important for preventing accidents and keeping people safe during events like religious gatherings, festivals and political rallies. The old ways of watching people like with security cameras are not good enough because they do not cover everything they are not flexible. They do not respond fast enough.

This project is about a system that uses drones and Artificial Intelligence to watch crowds and figure out if there are many people in one place especially in areas that are open or might be dangerous. A drone with a camera takes pictures of the crowd from the air and then a computer program like YOLOv8 looks at these pictures to find and count people calculate how crowded it is and see how people are moving. The system always checks this information against safety rules to see if there are many people. If it finds out that there are many people it sends out warnings and updates a special board that the people in charge can look at to take action right away.

This system is better than the ways because it can see more and it is more flexible. It also means that we do not need many people on the ground to watch the crowd, which helps us understand what is happening better and reduces the risk of people panicking or running into each other. Crowd management is really important. This system can help with that. The drone system can help keep people safe during events, like festivals and rallies.

**Keywords:** Drone Surveillance, Crowd Monitor-ing, YOLOv8, DeepSORT, Crowd Density Estimation, Anomaly Detection, Computer Vision, Public Safety.

## I. INTRODUCTION

Managing public gatherings like festivals, protests and emergency situations is a big challenge for people in charge. They have to make sure everyone is safe control the movement of people and prevent accidents. Usually crowd management is done by security people watching and using fixed cameras. This can be very time-consuming and not always accurate. It is also easy to make mistakes. This makes it hard to respond quickly when things change in a crowd in areas with a lot of people. So this project is about making a crowd monitoring system that uses drones and advanced computer techniques. Drones have high-resolution cameras that can show what is happening in an area in real-time, which is better than just using cameras on the ground. The video from the drones is analyzed using computer models that can automatically find people look at how crowded it is and watch how people are moving. This means people in charge can keep an eye on things without having to do it all themselves. The system can also find situations like too many people in one place, big groups of people gathering suddenly or people moving in a strange way.

When the system finds something it sends an alert to security people right away so they can take action quickly. This helps prevent things from happening like stampedes and makes sure people are safe. It also helps security people by reducing the amount of work they have to do and minimizing mistakes.

The system can be used in different situations like in smart cities at big events in transportation hubs and during disasters. Overall this project is an efficient way to manage crowds by using drones and computer analysis, which makes people safer and helps things run more smoothly. The crowd management system is a solution, for modern crowd management. It combines surveillance and computer-based analysis to enhance public safety and make things work better.

The crowd management system is reliable. Can be used to manage large public gatherings like festivals and emergency situations.

## II. OBJECTIVES

The main goal of this project is to stop overcrowding, stampedes and accidents during public events. This is done by using time aerial surveillance to spot areas with high crowd density. During festivals, protests or emergencies many people in one place can be very dangerous. Our system uses drones to monitor crowds from above giving a view of how people are spread out.

This helps spot congestion so authorities can take action like redirecting people or issuing warnings to prevent disasters. Another important goal is to use learning to accurately count people and track their movement. Our system uses models to detect individuals and follow them across multiple frames without counting them twice. This ensures we have an idea of crowd size and avoids counting people more than once. Our system is also designed to be privacy-friendly by focusing on how people move and gather not on who they're. The project also aims to create a cost and efficient drone-based system for monitoring crowds. Traditional surveillance systems can be expensive and limited. Drones on the other hand offer more flexibility and can cover a wider area at a lower cost. Our system can easily be scaled up or down to suit events and environments making it a practical solution for modern cities. The system also seeks to integrate crowd behavior analysis tools. These tools help authorities make decisions by analyzing crowd patterns, such as density and movement flow. This provides insights, in real-time helping officials respond quickly to potential threats and manage crowds more effectively. Overall these goals work together to build a reliable crowd management system that enhances safety and efficiency in large gatherings. The crowd management system helps to ensure public spaces. The system promotes innovation-driven approaches to infrastructure. The system enhances the efficiency of crowd control mechanisms.

### III. RELATED WORK

The proposed system uses an approach to achieve efficient real-time crowd monitoring and analysis. It uses drone-based surveillance and artificial intelligence. The process starts with data collection. Aerial crowd footage is captured using drones. This data represents crowd scenarios. The system is trained on conditions. Data collection is done using drones or existing datasets. The data includes gatherings, sparse populations and various movement patterns.

Next annotation is performed. Individuals and specific actions are labeled within images or video frames. Each person in the frame is marked using bounding boxes. Relevant behavior such as walking, running or lying down may also be labeled. The YOLOv8 training phase is then carried out. The annotated dataset is used to train the deep learning model. YOLOv8 learns to detect people in images. It classifies their presence accurately in time. The model adjusts its parameters through multiple training iterations. This improves detection accuracy. Reduces errors. Once trained the model can identify individuals in video footage.

The system then moves to drone integration. A camera is mounted on a drone to capture live video. The drone streams real-time footage to the processing system. This enables monitoring of large public areas. The next step is real-time detection. The trained YOLOv8 model processes video frames. It identifies people present, in the scene. Bounding boxes are generated around each detected individual. This allows the system to locate and count people instantly. Crowd analysis is then performed to extract insights. The system calculates the number of people. It estimates crowd density and analyzes movement patterns. The system performs anomaly detection. It identifies potentially risky behaviors. These include running, falling or individuals lying on the ground. The results are presented through dashboard alerts. All analyzed data is visualized in a understandable format. The dashboard displays crowd statistics and movement trends. It highlights anomalies. Generates real-time alerts. The system undergoes testing and validation. Its performance is evaluated using metrics. These include accuracy, precision, recall and response time. This ensures that the system works reliably under conditions. Overall this methodology combines data preparation, deep learning, drone technology and real-time analytics. It creates an intelligent crowd monitoring system. This enhances safety and efficiency in managing public gatherings.

### IV. PROPOSED METHODOLOGY

The system we are using is meant to help us watch crowds in time and understand what is going on using advanced computer vision techniques. It starts with pictures and videos from two sources: drones and CCTV cameras. Drones give us a view from above which is great for seeing big areas and understanding how crowds are spread out while CCTV cameras show us what is happening on the ground with detailed pictures of people and what they are doing. By using both of these views we can see everything that is going on in spaces, which makes our surveillance more accurate and effective.

Once we have the video the next step is to collect and prepare the data. We take the video and break it down into pictures so we can look at each one. We then format these pictures so they are ready for the AI model. We might also do some work to make the pictures clearer like reducing noise or improving the quality. This step is really important because if the data is good the model will work better and be more accurate. After we prepare the data we use the YOLOv8 model to look at each picture and find people in it. YOLOv8 is a good deep learning algorithm for finding objects and it can do it in real time. It draws boxes around each person it finds. Gives us a score that tells us how sure it is that it found someone. This step is crucial because it helps us know where people are and how many there are, which is important for the rest of our analysis.

Next we use the DeepSORT algorithm to track people as they move. While YOLOv8 finds people in pictures DeepSORT makes sure we can follow them as they move around. It gives each person an ID and tries to keep track of them even if they move, overlap with someone else or leave the picture for a moment. This helps us understand how people are moving and how crowds are flowing. It prevents us from counting someone twice.

Finally we show the results on a dashboard that's easy to use and understand. The dashboard shows us information like how crowded it is, where people are moving and if there are any potential problems like a big group of people gathering or someone acting strangely. This real-time view lets security people or authorities watch what is going on and respond quickly if there is a problem.

The crowd monitoring system we are using combines all these steps. Taking videos preparing data finding objects tracking people and showing the results. Into one system. It helps us watch crowds in time which makes it easier to keep people safe manage crowds and make good decisions in critical situations. The crowd monitoring system is very helpful for crowd monitoring it helps with crowd monitoring. It is good, at crowd monitoring.

### V. SYSTEM ARCHITECTURE

The crowd density analysis system is made up of parts that work together. It starts with getting the data, which is done by drones with quality cameras that take videos of public places in real time. Sometimes CCTV cameras are also used to get views from the ground. These videos are sent to the part of the system that processes the data using communication. Next the video is broken down into pictures. These pictures are made smaller made to be the same and formatted so that the deep learning model can use them. This makes sure the data is good and ready to be used. Then the pictures are sent to the part of the system that detects things, where the YOLOv8 model is used. This model finds people in each picture. Draws boxes around them. It also gives each person a score to make sure it is correct. This part is very important because it helps the system find people quickly and reliably.

After that the system uses the DeepSORT algorithm to track the people it found. This gives each person a number and tracks where they move in each picture. It can even keep track of people when they are blocked by something or someone else which helps the system understand how people are moving.

The next part is where the system looks at the data and figures out things about the crowd. This includes how many people are there how they are. If there is anything unusual going on like people running or a big group of people. Then the results are sent to the part of the system that shows the information in a user way. This is like a dashboard that shows how crowded it is, where people are moving and if there are any problems. It also sends warnings to security people if it finds something that might be a problem so they can respond quickly.

Finally the system stores all the data and results so that it can be used later to make the system better. This part also tests the system to make sure it is working well and quickly. The crowd density analysis system is a combination of drones, deep learning and real time analysis that works together to make a good crowd monitoring system. The crowd density analysis system uses crowd density analysis to make sure everything works well. The crowd density analysis system is very good, at crowd density analysis.

1) Data Acquisition: Data acquisition is the initial stage where input is collected for the system. It involves capturing real-time video footage using drones and CCTV cameras. Drones provide an aerial view, which is useful for monitoring large crowds and open areas, while CCTV cameras offer a ground-level perspective for detailed observation.

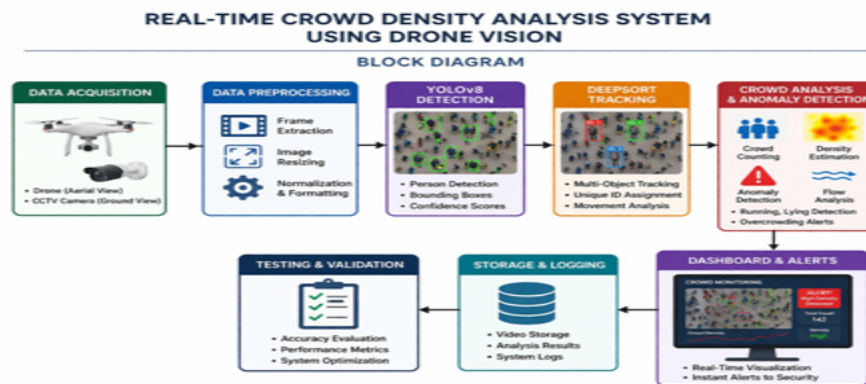


Fig.1.

This combination ensures complete coverage of the environment and improves the accuracy of crowd monitoring.

#### 2) *Data Preprocessing:*

Data preprocessing is performed to convert raw video data into a suitable format for analysis. First, the video stream is divided into individual frames through frame extraction. These frames are then resized to match the input dimensions required by the AI model. Additionally, normalization and formatting are applied to maintain consistency in data quality. This step enhances the efficiency and accuracy of the detection process.

#### 3) *YOLOv8 Detection:*

In this stage, the YOLOv8 deep learning model is used to detect people in each frame. The model processes the input images and identifies human objects by drawing bounding boxes around them. It also assigns confidence scores to indicate the reliability of each detection. YOLOv8 is designed for real-time performance, making it suitable for continuous surveillance applications where quick and accurate detection is required.

#### 4) *DeepSORT Tracking:*

DeepSORT is used to track detected individuals across multiple frames. It assigns a unique identity (ID) to each person and follows their movement throughout the video. Even when people overlap or temporarily disappear from view, the algorithm attempts to maintain consistent tracking. This helps in analyzing movement patterns and prevents counting the same person multiple times.

#### 5) *Crowd Analysis:*

Crowd analysis focuses on extracting meaningful insights from detected and tracked data. The system counts the total number of individuals present in the frame and calculates crowd density based on the number of people per unit area. It also analyzes the movement flow of the crowd, identifying how people are moving within the monitored space. This information is useful for understanding crowd behavior and managing congestion.

#### 6) *Anomaly Detection:*

This stage identifies unusual or abnormal activities within the crowd. The system detects behaviors such as sudden running, people lying on the ground, or unexpected crowd gatherings. These anomalies may indicate emergencies, panic situations, or security threats. Early detection of such events allows authorities to respond quickly and prevent accidents.

#### 7) *Dashboard Alerts:*

The processed information is displayed on a monitoring dashboard in a user-friendly format. The dashboard shows crowd count, density levels, movement patterns, and detected anomalies. In case of any abnormal situation, the system generates real-time alerts to notify security personnel. This helps in quick decision-making and effective crowd management.

#### 8) *Testing Storage:*

In the final stage, the system is tested and evaluated to ensure reliable performance. Metrics such as accuracy, precision, and response time are used to measure effectiveness. At the same time, video data, analysis results, and system logs are stored for future reference and improvement. This step helps in optimizing the system and maintaining long-term efficiency.

## VI. LIMITATIONS AND CHALLENGES

The drone crowd monitoring system faces challenges. One big challenge is detecting people from up. When people are packed closely together it is hard to count and track them accurately. The drones' movement and shaky camera footage make it even harder. Weather conditions like lighting, rain, and fog affect the video quality. The system needs a lot of computer power to process high-quality video in time. This can make the system expensive and slow. Also, drones can only fly for a time, which limits how long they can monitor a crowd. There are also some limitations to the system. It does not work well in crowded areas. The camera quality and video resolution are important for detection. At night the system may need cameras.

The project has to follow drone flight rules and laws in areas. Some people may worry about their privacy with surveillance. The AI model may need to be updated if it is used in a place or with a different crowd. With these limitations, the system is a good solution for monitoring crowds and keeping people safe. The drone crowd monitoring system faces challenges.

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## VII. SECURITY AND PRIVACY CONSIDERATIONS

The proposed system uses drones and artificial intelligence to keep an eye on areas all the time. So it is really important that we keep the data safe and private. The videos that the drone take might have information that we do not want to share. Therefore we need to make sure that the data is encrypted when it is being sent and when it is being stored. This way nobody can get to it without permission. Only the people who are allowed to see the videos and the monitoring dashboard should be able to get in. We need to have security so that only these people can see or manage the data. The system should not keep any information that it does not need. It might be an idea to blur faces in the videos so that we cannot see who people are.

We have to make sure that we are following all the rules about using drones to watch people and that we are protecting people's privacy. When the drones are talking to the servers and the dashboards they need to use channels. This way the bad people cannot get to the videos. Change them or steal them. We need to have rules about how we use the system and we need to be honest, about how it works. This way we can make sure that we are using the system in a way when we are watching people in public. The proposed system should do all these things to keep people's data safe and private.

## VIII. CONCLUSION

This project is about using drones to watch crowds in time. It is an efficient way to do this. The system uses models to find objects and track them. This means it can tell who is there how many people are in the crowd and what they are doing. Drones can see a lot of people at once which is hard to do with regular cameras.

The system can also find problems like many people in one place or people moving quickly.

This helps the police know what is happening so they can stop accidents like people getting hurt in a crowd. The system is automatic so people do not have to watch everything all the time. This means there are mistakes and it works better. The project is a way to manage crowds because it is big enough to work for many people it does not cost too much and it is smart. It is useful for things, like concerts, big gatherings and emergencies. The crowd monitoring system using drones is an idea because it helps keep people safe. The drones and the system work together to make sure everything is okay. The project is an example of how crowd monitoring can be done in a smart way.

## IX. FUTURE SCOPE

This project is about using drones to watch crowds in time. It is an efficient way to do this. The system uses models to find objects and track them. This means it can tell who is there how many people are in the crowd and what they are doing. Drones can see a lot of people at once which is hard to do with regular cameras.

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