

Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5

Tejashree Shende

Department of Computer Engineering
(Student)

Sinhgad College of Engineering
(SPPU)

Pune, India

shendetejashree22@gmail.com

Sanika Shirsat

Department of Computer Engineering
(Student)

Sinhgad College of Engineering
(SPPU)

Pune, India

sanikashirsat31@gmail.com

Radhika Patil

Department of Computer Engineering
(Student)

Sinhgad College of Engineering
(SPPU)

Pune, India

patilradhikam@gmail.com

Mansi Shinde

Department of Computer Engineering
(Student)

Sinhgad College of Engineering
(SPPU)

Pune, India

mansidshinde2608@gmail.com

Ajit Karanjkar

Department of Computer Engineering
(Assistant Professor)

Sinhgad College of Engineering
(SPPU)

Pune, India

amkaranjkar.scoe@sinhgad.edu

Abstract -- Crowd monitoring has become important in places such as malls, railway stations, and public events where large numbers of people gather every day. Traditional CCTV systems only record video and mostly depend on security staff to continuously observe the footage, which becomes difficult during crowded situations. Because of this, detecting overcrowding or unusual activities on time is not always possible. This project focuses on developing a real-time crowd analysis and smart surveillance system using YOLOv5. The system detects people from live video frames and calculates the crowd count to estimate density. When the number of people crosses a fixed limit, an alert is generated automatically. The project also includes a basic anomaly detection feature that observes movement patterns to identify unusual activities such as sudden running or abnormal motion. A Streamlit dashboard is used for displaying live video feed, detection results, crowd statistics, and alert messages in real time. The model was tested on the UCSD Pedestrian and Mall datasets along with live camera input. The obtained results show that the system can perform crowd monitoring with good accuracy and real-time processing speed, making it useful for practical surveillance applications.

Keywords-- Crowd Monitoring, YOLOv5, Computer Vision, Real-Time Surveillance, Anomaly Detection, Crowd Density Estimation, BotSort Tracking, CCTV Monitoring, Streamlit Dashboard, Telegram Alerts.

I. INTRODUCTION

The population is growing fast and more people are moving to cities. This means that a lot of people are gathering in places like shopping malls, train stations, airports, stadiums and events. It is a challenge for security people to keep everyone safe in these crowded places. When there are many people it can get scary and things can go wrong. If security people do not see what is happening away it can be very bad.

In the few years new technologies like Artificial Intelligence and Computer Vision have made it possible to make smarter surveillance systems. These systems can look at video footage. Find people watch how crowds are moving and see what is going on in real time. One of the popular ways to do this is with something called YOLO. It is very good at finding things in videos. Studies have shown that YOLO can really help with watching crowds and keeping people safe.

There are already some systems that watch crowds. They are not very good. Some of them can only record video. Do not really look at what is happening. Others get confused when there are many people. Sometimes when people are acting strange these systems do not see it away. This can be very bad.

A lot of these systems also do not send out warnings when something is wrong so security people do not know what is happening.

To make things better we made a new system called "Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5". It uses YOLOv5 to find people and another system to track them. It can also see when there are many people and when something strange is happening. If something is wrong it sends a warning message with a picture. The system looks at video footage in time to see what is happening.

We also made a dashboard that shows what is happening on the video feed. It shows statistics about the crowd and any warning messages. When something is wrong the system sends a warning message with a picture. This helps security people see what is happening and keeps everyone safer. Our system is smart, easy to use. Helps keep people safe in public places.

The system is very good at finding people and watching crowds. It uses YOLOv5 and other technologies to make sure everything is safe. It is a good way to keep people safe in crowded places. Crowd safety is very important. Our system helps with that.

The system can look at video footage. See what is happening. It can find people. Watch how they are moving. It can also see when something strange is happening. This helps security people know what is going on and keeps everyone safe. The system is very good at sending out warnings when something's wrong.

We think our system is a good way to keep people safe, in crowded places. It is smart, easy to use. Helps security people do their job. We hope it will be used in public places to keep people safe. Crowd safety is very important. We think our system can help with that. We think that our system will be very useful in real time problems that are caused due to overcrowding or no certain detection of what is happening in the frames.

II. LITERATURE SURVEY

In the few years crowd monitoring and intelligent surveillance systems have become really important because more and more people are gathering in public places like malls, railway stations, airports, stadiums and big public events. It is hard to manage crowd safety in these places because many people can cause panic and create big security risks. To make surveillance systems better researchers have used things like Artificial Intelligence, Deep Learning and Computer Vision to improve how we watch crowds and find people.

One big help in this area is a paper called "You Look Once: Unified Real-Time Object Detection" by Joseph Redmon and his team. They made a model called YOLO that uses one network to find objects and it is faster than old methods. This research showed that YOLO can find objects in time and is still very accurate which makes it great for surveillance and crowd monitoring.

Another important work is "YOLOv4: Speed and Accuracy of Object Detection" by Alexey Bochkovskiy and his team. They worked on making object detection more accurate. They made a model called YOLOv4 that has some optimization techniques that make it work better in real-time. This research showed that we need to balance speed and accuracy for surveillance applications that use video.

Research on crowd monitoring has also looked at counting people. How they behave. A paper called "Privacy Preserving Crowd Monitoring: Counting People Without People Models or Tracking" by A. B. Chan and his team talked about ways to analyze crowd density without tracking each person. They showed that automated crowd estimation systems can make monitoring more efficient in public places.

Another big contribution is the research called "Abnormal Crowd Behavior Detection using Social Force Model" by R. Mehran and his team. They worked on finding crowd behavior by looking at how people move. They looked at crowd motion patterns to find activities like panic situations or sudden running. This study showed that automated anomaly detection systems can help keep people safe and respond to emergencies.

Tracking algorithms have also been important in surveillance systems. A paper called "Simple Online and Realtime Tracking with a Deep Association Metric (DeepSORT)" by N. Wojke and his team made a tracking system that can keep track of objects from one frame to the next. The ByteTrack and BotSort tracking approaches also made tracking in crowded places by reducing mistakes and handling overlapping objects. These studies showed that combining object detection with tracking algorithms makes crowd monitoring more accurate.

Even though many surveillance systems can detect people count crowds or analyze movement most of them only do one thing. Some systems are not good at tracking people in crowds and others do not send alerts in real-time or analyze anomalies. In cases people still need to watch the systems all the time, which makes them less efficient. After looking at what's already out there we still need a system that combines real-time people detection crowd density estimation, anomaly detection, tracking and automated alert generation all in one place. To fix these problems a new system called "Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5" is being made. It uses YOLOv5-based detection YOLOv8-assisted tracking, BotSort tracking, anomaly analysis, Telegram alert generation and Streamlit-based live visualization to provide a practical real-time surveillance system. Crowd monitoring and intelligent surveillance systems like this one are very important, for crowd safety. The YOLOv5 system is designed to make surveillance more efficient and effective.

III. PROBLEM STATEMENT

Keeping people safe in places like malls, railway stations, airports, stadiums and public events is a big problem. More and more people are gathering in these places. The old way of watching people with CCTV cameras is not working well. This is because security people have to keep watching the cameras all the time which's hard to do when there are many cameras to

watch at the same time. When there are a lot of people important things like many people, suspicious behavior or people running around can be missed. This makes it less safe for everyone.

Most surveillance systems just record video. Do basic watching. They do not use ways to analyze crowds find unusual behavior or send out warnings automatically. Some systems have trouble working well when there are a lot of people close together. This makes it hard to track what is happening. Keep an eye on things. If unusual behavior is not found away it can slow down the response to emergencies and make it less safe for the public.

The system we are talking about "Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 " is designed to be an automatic way to watch crowds. It uses intelligence to find objects, track people analyze unusual behavior and send out warnings in real time. This will help keep people safe in places. The Real-Time Crowd Analysis system is a solution for crowd monitoring and public safety. It uses AI to make sure everyone is safe. The Real-Time Crowd Analysis system is the key, to making crowded places safer.

IV. PROPOSED SYSTEM

The proposed system, "Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 " is a computer program that helps watch over crowds in time. It uses intelligence to look at CCTV footage and live webcam feeds. This system is made up of parts: video input, object detection, tracking, anomaly analysis and alert generation.

It works by capturing video frames and using YOLOv5 to detect people in real-time. The system then uses BotSort tracking with YOLOv8 to give each person an ID and track them across frames. This helps the system to calculate how crowded an area is and look at how people are moving. If it sees anything like people suddenly running or moving strangely it will flag it. Whenever the system detects overcrowding or suspicious behaviour it sends out messages on Telegram along with pictures. This way authorities can respond quickly to problems.



Fig 1. System Architecture

Fig. 1 illustrates the system architecture of the proposed crowd monitoring system. The system captures live video input

from CCTV or webcam feed, processes frames using YOLOv5 for people detection and BotSort for tracking, performs crowd density and anomaly analysis, generates Telegram alerts, and displays monitoring results through the Streamlit dashboard.

A dashboard made with Streamlit shows video feeds, crowd statistics, tracking information and alerts in real-time. The goal of this system is to make it easier to monitor crowds while needing people to watch all the time. The Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 aims to provide a solution, for improving public safety in crowded environments with the help of YOLOv5.

V. EXISTING SYSTEM

Existing surveillance systems can do things like record videos watch CCTV footage manually detect people and count crowds. Some modern systems use AI to identify people in videos while others look at movement or track people. These systems make surveillance a bit better. Most of them only do one thing and do not offer a complete solution for monitoring crowds. Many existing systems also struggle in areas because people overlap tracking is not accurate and it takes a while to spot suspicious activities.

To fix these problems our proposed system called "Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5" brings together people detection using YOLOv5 tracking with YOLOv8 and BotSort estimating crowd density detecting anomalies sending alerts via Telegram and live visualization using Streamlit. This creates a smart surveillance platform.

TABLE 1. COMPARISON TABLE OF EXISTING VS PROPOSED SYSTEM

Parameters	Existing Systems	Proposed System
Crowd Monitoring	Basic Monitoring	Real-time intelligent monitoring
Object Detection	Limited accuracy	YOLOv5-based accurate detection
Tracking	Basic or unavailable	BotSort tracking with unique IDs
Crowd Density Analysis	Limited support	Real-time crowd density estimation
Anomaly Detection	Mostly Unavailable	Suspicious activity detection
Alert Generation	Manual monitoring required	Automatic System and Telegram alerts
Live Monitoring	Limited visualization	Streamlit live dashboard
Scalability	Limited	Scalable real-time system
User Dependency	High human dependency	Reduced manual monitoring
System Integration	Separate functionalities	Integrated all-in-one platform

Table 1 compares existing surveillance systems with our proposed system. It shows that our system is better at detecting people tracking them in time analyzing crowds sending automatic alerts and monitoring live feeds. This makes our system more useful, for real-life surveillance applications.

VI. MATERIALS AND METHODS

The proposed system, "Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5," is developed using modern AI-based computer vision technologies and standard hardware resources to provide efficient real-time crowd monitoring and intelligent surveillance. The technologies used in the system support real-time object detection, tracking, anomaly analysis, live visualization, and automated alert generation.

A. Software Requirements

- **Python** – Used for implementing system logic, object detection, tracking, and anomaly analysis.
- **YOLOv5** – Used for real-time people detection from video frames.
- **YOLOv8** – Used during the tracking phase for improved tracking support.
- **BotSort** – Used for multi-object tracking and maintaining unique IDs across frames.
- **OpenCV** – Used for image processing and live video feed handling.
- **Streamlit** – Used for developing the real-time monitoring dashboard.
- **Telegram Bot API** – Used for generating automated alert notifications.
- **Visual Studio Code / PyCharm** – Used as the development environment.

B. Hardware Requirements

- **Processor** – Intel i5 or higher
- **RAM** – Minimum 8 GB
- **Storage** – Minimum 20 GB free space
- **Device** – Laptop or desktop system with webcam support
- **Camera** – Laptop webcam or external CCTV camera
- **GPU** – NVIDIA GPU recommended for faster processing
- **Internet Connection** – Required for Telegram alert services and real-time monitoring

VII. EXPERIMENTAL RESULT

The Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 was tested to see how well it works. We wanted to know if it can detect people accurately and track them in time. The system was set up using a live webcam feed and some videos of people walking. All the main parts of the system worked well during testing.

The YOLOv5 model was very good at detecting people in videos even when it was hard to see them. It worked well in both crowded areas. The BotSort tracking system was able to keep track of each person and give them an ID. The crowd density estimation part of the system counted the number of people in each video frame. Sent an alert when there were too many people.

The system could also detect when people were moving strangely like running or walking in a way. It would send an alert to Telegram when it saw something along with a picture of what was happening. The Streamlit dashboard showed the

video feed, detection results and tracking information in real time. This made it easy to monitor and analyze the crowd.

The testing results showed that the Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 is a solution for monitoring crowds. It uses intelligence to detect webcam feed and some videos of people walking. All the main parts of the system worked well during testing.

The YOLOv5 model was very good at detecting people in videos even when it was hard to see them. It worked well in both crowded areas. The BotSort tracking system was able to keep track of each person and give them an ID. The crowd density estimation part of the system counted the number of people in each video frame. Sent an alert when there were too many people.

The system could also detect when people were moving strangely like running or walking in a way. It would send an alert to Telegram when it saw something along with a picture of what was happening. The Streamlit dashboard showed the video feed, detection results and tracking information in real time. This made it easy to monitor and analyze the crowd.

The testing results showed that the Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 is a solution for monitoring crowds. It uses intelligence to detect and track people and it sends alerts when something suspicious happens. This makes it easier to monitor crowds without having to watch the videos all the time.

TABLE 2. PERFORMANCE ANALYSIS OF THE PROPOSED SYSTEM

Parameters	Results
People Detection	Real-time and accurate
Crowd Density Estimation	Successfully implemented
BotSort Tracking	Stable tracking achieved
Anomaly Detection	Suspicious activities identified
Telegram Alerts	Real-time alerts generated
Live Dashboard	Successfully implemented
Detection Speed	Real-time processing achieved
User Interface	User-friendly and interactive

Table 2 shows how well the Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 works. It highlights the things the system can do like detecting people and tracking them in real time. The results show that the system is good at monitoring crowds and sending alerts when something suspicious happens.

The live crowd monitoring dashboard as shown in Fig. 2 Shows the video feed and detection results in real time. It also shows crowd statistics and alert notifications. The dashboard is interactive so users can easily analyze the crowd.



Fig 2. Streamlit Dashboard Detection



Fig 3. YOLOv5 Person Detection of Mall Dataset

The people detection output of the Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 is shown in fig 3. It shows that the model can detect people accurately in video frames. It draws boxes around people it detects. It also shows a confidence score.

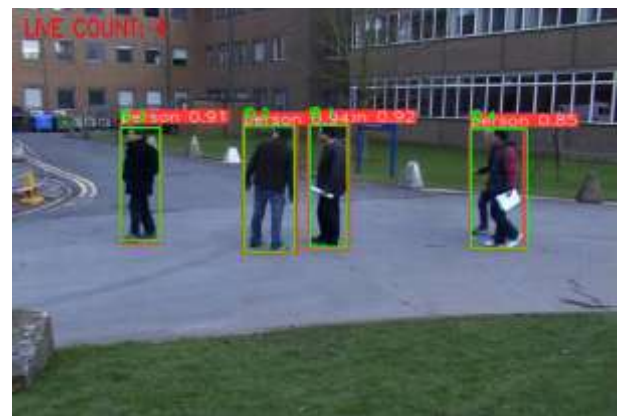


Fig 4. BotSort Tracking Output

The BotSort tracking mechanism, as shown in Fig. 4 Tracks people across video frames by giving them an ID. It can even track people when they overlap or move out of the frame for a moment.

The Telegram alert generation system, as shown in Fig. 5 Sends alert notifications and pictures when it detects overcrowding or suspicious behavior. This helps improve real-time surveillance and emergency response.



Fig 5. Telegram Alert Notification System

VIII. MATHEMATICAL MODEL

The mathematical model of the proposed system Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 shows how the system works. It includes collecting video input detecting people estimating crowd density tracking individuals analyzing anomalies and generating alerts.

The system takes video frames from CCTV cameras or webcam feeds processes them using AI-based object detection and tracking algorithms and generates real-time monitoring results and alerts.

A. Mathematical Representation

Let's define some variables:

- (F) is the set of input video frames
- (D) is the number of people detected
- (T) is the tracking information of detected individuals
- (C) is the crowd density value
- (A)'s the anomaly detection result
- (L) is the alert notification generated by the system

The system input can be represented as:

$$Input = \{F\}$$

The people detection function is represented as:

$$D = f(F)$$

Where:

- D= Detected people in the video frame
- f= YOLOv5 object detection function

The tracking function is represented as:

$$T = g(D)$$

Where:

- T= Tracking information with unique IDs
- g= BotSort tracking function

The crowd density estimation is calculated as:

$$C = \frac{D}{Area}$$

Where:

- C= Crowd density value
- D= Total number of detected individuals

The anomaly detection function is represented as:

$$A = h(T)$$

Where:

- A= Detected suspicious activity
- h= Movement analysis and anomaly detection function

The alert generation function is represented as:

$$L = k(C, A)$$

Where:

- L= Telegram alert notification
- k= Alert generation function based on crowd density and anomaly detection

B. Time Complexity

The time complexity of the proposed system is:

$$O(n)$$

Where:

- n represents the number of processed video frames, detected objects, tracking operations, and anomaly analysis processes.

Since the system processes video frames sequentially for detection, tracking, and crowd analysis, the overall execution time increases linearly with the number of processed frames.

C. Space Complexity

The space complexity of the system is:

$$O(n)$$

Where:

- n represents the amount of stored frame data, tracking information, detection outputs, anomaly records, and alert history.

The system efficiently manages memory usage while supporting real-time processing, live monitoring, and alert generation.

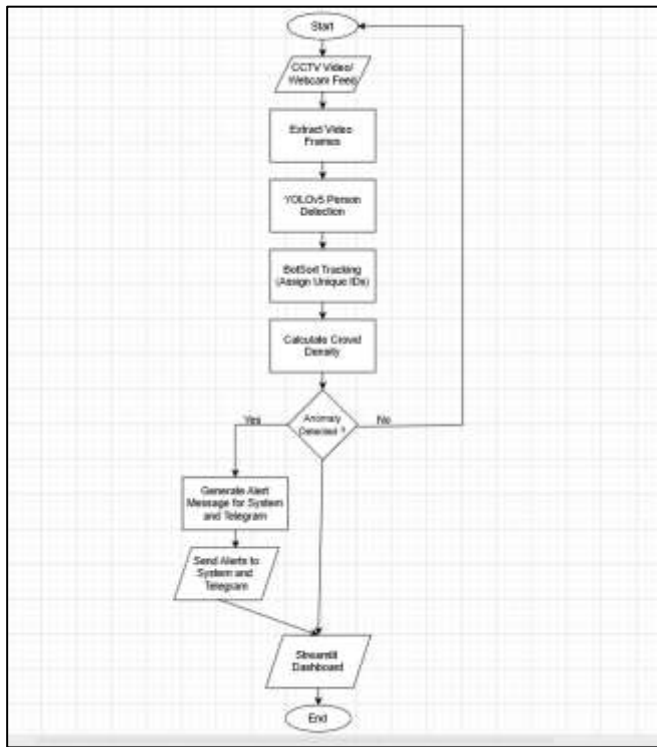


Fig. 6. Flow Chart

The Fig. 6 Flow Chart of the proposed crowd monitoring system shows the workflow of the application. It represents the sequence of operations performed during real-time surveillance and crowd analysis. The flow chart provides a visualization of how video frames are processed through detection, tracking, anomaly analysis and alert generation modules.

The workflow starts when the system captures video input from CCTV cameras or webcam feeds. The captured frames are processed using the YOLOv5 object detection model to identify people in the scene. After detection the BotSort tracking mechanism assigns unique IDs to detected individuals. Tracks their movement across consecutive frames. The system then calculates crowd density and analyzes movement patterns to identify activities such as sudden running or overcrowding situations.

Whenever the crowd count exceeds the predefined threshold value or abnormal crowd behavior is detected the system automatically generates Telegram alert notifications along with captured anomaly images. Finally all monitoring results, crowd statistics, tracking information and alert messages are displayed through the Streamlit dashboard, for real-time surveillance and analysis.

IX. SIMULATION RESULT

The Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 was tested to see how it works with people detection, crowd monitoring, tracking, anomaly analysis and alert generation. The Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 worked well with webcam feed and video input from a dataset.

It did this in a responsive manner. The YOLOv5 model was good at finding people in video frames. The BotSort tracking mechanism was also good at tracking people from one frame to the next. The Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 could check crowd density all the time. It sent notifications on Telegram when there were too many people or something suspicious was happening.

The Streamlit dashboard showed crowd statistics tracking information and live monitoring results in time. The Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 worked well.

The simulation results show that the Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 is a solution for monitoring crowds and watching people in real time.

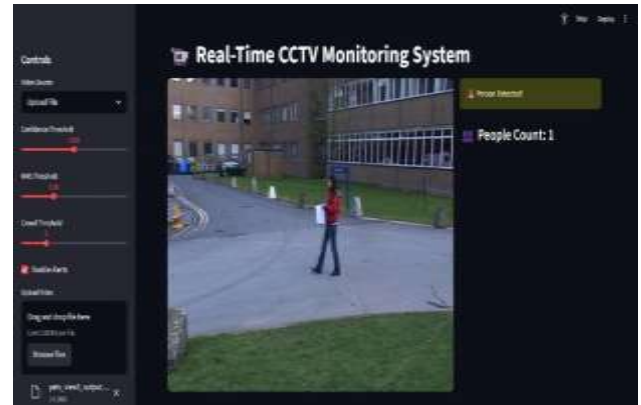


Fig 7. Streamlit Dashborad

The Streamlit dashboard of the Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 as shown in Fig. 7 Gives us a way to watch live CCTV or webcam feed, crowd statistics people detection results, tracking information and alert notifications in time. The dashboard helps users understand crowd conditions in a way.

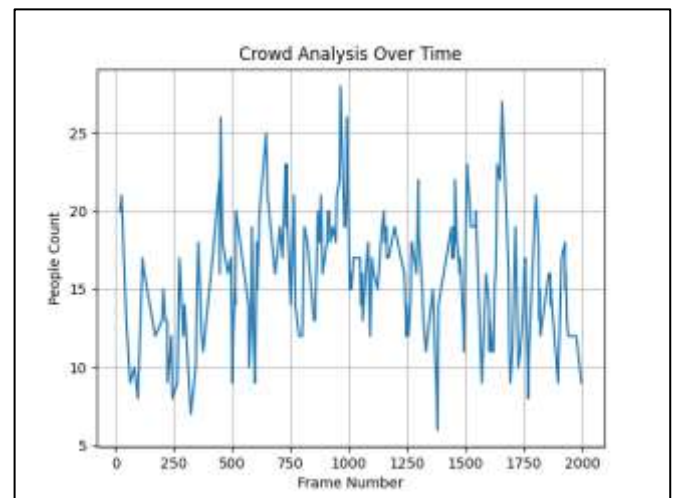


Fig 8. Detection graph of Mall Dataset

Fig 8 shows a graph generated by the model. It shows the people count against frame number of the Mall dataset. The graph shows number of people detected in each frame. It is mostly above 10 people because the dataset contains large crowds in each frame.

X. CONCLUSION

The number of people in places like malls, railway stations, airports, stadiums and events is increasing really fast. This makes it very hard to keep everyone safe and watch what is happening all the time. The old CCTV systems need someone to watch them all the time, which's not easy for security people to do. They have to look at videos at the same time and find anything suspicious or if there are too many people in one place. This is why we need a system that can watch the crowd and keep people safe without needing someone to always be watching.

This project is about making a system called "Real-Time Crowd Analysis and Supervised CCTV System Using

YOLOv5". This system uses computer programs to find people track where they are going see how crowded it is find anything strange watch live and send alerts on Telegram. It looks at the videos from CCTV cameras and live webcams in time to find people see where they are moving check the crowd and find anything suspicious automatically.

The YOLOv5 program is very good at finding people in time. The BotSort program helps keep track of people by giving them an ID. The system can also see if there are many people or if they are behaving strangely like running suddenly. If it finds anything suspicious it sends an alert, on Telegram with a picture of what's happening. This helps security people respond quickly.

The system has an interface called Streamlit that shows the live video, crowd information tracking details and alerts in real time. It is easy to use and understand. When we tested the system it worked well with videos and live webcam input. It found people. Tracked them accurately.

Overall this system is an better way to watch crowds and keep people safe. It uses computer programs to find people track them and send alerts, which makes it easier for security people to do their job. This project shows how computer vision and deep learning can be used to keep people safe and make surveillance systems better. The Real-Time Crowd Analysis and Supervised CCTV System Using YOLOv5 is an example of how technology can be used to improve public safety.

REFERENCES

- [1] J. Redmon, S. Divvala, R. Girshick and A. Farhadi wrote a paper called "You Look Once: Unified Real-Time Object Detection" in the Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition which was held in 2016. This paper is on pages 779–788.
- [2] A. Bochkovskiy, C.-Y. Wang and H.-Y. M. Liao wrote a paper called "YOLOv4: Speed and Accuracy of Object Detection" in 2020. You can find this paper on the arXiv website.
- [3] G. Jocher and his team created a GitHub Repository for YOLOv5 by Ultralytics in 2020. You can find the repository at <https://github.com/ultralytics/yolov5>.
- [4] A. B. Chan, Z.-S. J. Liang and N. Vasconcelos wrote a paper called "Privacy Preserving Crowd Monitoring: Counting People Without People Models or Tracking" in the Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition which was held in 2008. This paper is on pages 1–7.
- [5] R. Mehran, A. Oyama and M. Shah wrote a paper called "Abnormal Crowd Behavior Detection Using Social Force Model" in the Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition which was held in 2009. This paper is on pages 935–942.
- [6] N. Wojke, A. Bewley and D. Paulus wrote a paper called "Simple Online and Realtime Tracking with a Deep Association Metric" in the Proceedings of the IEEE International Conference on Image Processing, which was held in 2017. This paper is on pages 3645–3649.
- [7] Y. Zhang and his team wrote a paper called "ByteTrack: -Object Tracking by Associating Every Detection Box" in the Proceedings of the European Conference on Computer Vision, which was held in 2022. This paper is on pages 1–21.
- [8] R. Girshick wrote a paper called "Fast R-CNN" in the Proceedings of the IEEE International Conference on Computer Vision, which was held in 2015. This paper is on pages 1440–1448.
- [9] B. Yang, R. Cao and X. Zhang wrote a paper called "Real-Time Crowd Density Monitoring Using Deep Learning Techniques" in the International Journal of Computer Vision and Image Processing in 2021. This paper is in volume 12 number 3. Is on pages 45–56.
- [10] S. Khan and M. Hussain wrote a paper called "AI-Based Intelligent Surveillance System for Crowd Monitoring and Anomaly Detection" in the International Journal of Advanced Computer Science and Applications in 2022. This paper is in volume 13 number 4. Is on pages 210–218.
- [11] The OpenCV Documentation is available at <https://opencv.org/>.
- [12] The Streamlit Documentation is available at <https://streamlit.io/>.
- [13] The Telegram Bot API Documentation is available at <https://core.telegram.org/bots/api>.
- [14] The PyTorch Documentation is available at <https://pytorch.org/>.
- [15] The UCSD Pedestrian Dataset is available at <http://www.svcl.ucsd.edu/projects/anomaly/dataset.htm>.
- [16] The Mall Dataset is available at https://personal.ie.cuhk.edu.hk/~ccloy/downloads_mall_dataset.html.
- [17] A. Geiger, P. Lenz and R. Urtasun wrote a paper called "Are We Ready for Autonomous Driving? The KITTI Vision Benchmark Suite" in the Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition which was held in 2012. This paper is on pages 3354–3361.
- [18] S. Ren, K. He, R. Girshick and J. Sun wrote a paper called "Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks" in the IEEE Transactions on Pattern Analysis and Machine Intelligence in 2017. This paper is in volume 39 number 6. Is on pages 1137–1149.
- [19] M. Everingham and his team wrote a paper called "The Pascal Visual Object Classes (VOC) Challenge" in the International Journal of Computer Vision in 2010. This paper is in volume 88 number 2. Is on pages 303–338.
- [20] D. Lowe wrote a paper called "Distinctive Image Features from Scale-Invariant Keypoints" in the International Journal of Computer Vision in 2004. This paper is in volume 60 number 2. Is, on pages 91–110.