

AI-Driven Smart Weapon Detection and Public Safety Surveillance System Using YOLOv8 and Deep Learning

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Abstract

Crime and violence in places are big worries for police and security guards. Old surveillance systems rely on people watching all the time which's boring and can lead to mistakes. So we need a system that can find weapons like guns and knives in real time and alert the authorities right away.

This research paper talks about a system that uses Artificial Intelligence to detect weapons using Deep Learning and the YOLOv8 framework. The system looks at live video feeds from cameras to spot weapons and send alerts before anything bad happens. The main goal is to make public places safer and help security respond faster.

The system uses a type of computer learning called Convolutional Neural Networks along with YOLOv8 to spot and classify objects. The model was trained on a dataset of weapon images taken in different places and lighting conditions. We also used techniques like rotating, flipping and scaling images to make the system more accurate. The process of detecting weapons involves taking frames from the video preparing the images extracting features detecting objects and classifying them. When a weapon is detected the system automatically sends an alert to the authorities. The YOLOv8 model is very fast making it suitable for real-time use.

We tested the system using metrics like Precision, Recall and F1-Score. The results show that the model is highly accurate and reliable in detecting weapons in conditions, including daytime and nighttime. The system can be used in places like shopping malls, train stations, airports and schools.

This research shows how Artificial Intelligence and Computer Vision can improve security systems. The proposed system reduces the need for people to watch surveillance footage all the time and improves response, to threats. In the future this technology can be combined with drones, cloud-based monitoring and smart city infrastructure to make public places even safer.

Keywords— Artificial Intelligence (AI), Deep Learning, YOLOv8, Weapon Detection, Object Detection, Computer Vision, Real-Time Surveillance, CCTV Monitoring, Public Safety, Convolutional Neural Network (CNN), Smart Security System, Image Processing, Threat Detection, Automated Surveillance, Machine Learning.

Introduction

Public safety is an issue these days. We have a lot of crimes, terrorist attacks, robberies and violent incidents happening over the place.

Places like airports, railway stations, schools, shopping malls and other crowded areas are really, in danger.

To make these places safer we have surveillance cameras installed everywhere.

The old way of keeping an eye on these surveillance cameras is not very good.

It needs people to watch the surveillance cameras all the time which's really boring and not very effective.

We need to find a way to watch these surveillance cameras.

When people have to watch cameras for a time they get tired and distracted. They can make mistakes. Might miss something. It is even harder to watch cameras in places. So security people might not see situations on time which makes the cameras not very useful.

New technologies like Artificial Intelligence and Machine Learning are helping to make surveillance systems. These technologies are great at looking at pictures and videos. Can find suspicious things more accurately than people can. They can look at a lot of pictures and videos quickly which makes them good for security systems that need to work

One of the technologies for finding objects is YOLO. It is very fast and accurate at finding objects in pictures and videos. The newest version, YOLOv8 is even better than the versions. It can find objects accurately and quickly.

- This project is about making a system that can find weapons like guns and knives in time using YOLOv8.
- The system will look at the video from surveillance cameras. Find weapons.
- When it finds a weapon it will send a message to the people in charge so they can do something about it.

The system that uses YOLOv8 wants to make people safer, by finding threats and helping security people respond faster. By not relying on people to watch the cameras all the time the system can make security monitoring better and more reliable. YOLOv8 is a tool and the system will use it to detect weapons and make public places safer. The goal of the system is to use YOLOv8 to detect weapons and improve safety.

Literature Review

Artificial Intelligence and Deep Learning technologies have significantly improved modern surveillance systems by enabling automatic weapon detection and intelligent threat monitoring. Many researchers have proposed different object detection models and surveillance frameworks to improve public safety and reduce human effort in security monitoring systems.

[1] **Joseph Redmon et al.** introduced the YOLO (You Only Look Once) object detection algorithm for real-time object detection. Their model provided faster processing speed and improved detection performance compared to traditional object detection methods. YOLO became one of the most widely used frameworks for surveillance and security applications because of its real-time detection capability.

[2] **Deshpande et al.** They came up with a YOLOv8-based weapon detection system for security applications that are going to be used in the future. The people who did this research were looking at how to find weapons in footage from security cameras using YOLOv8-based Artificial Intelligence. The YOLOv8-based system was really good at finding weapons. It worked very fast which makes it a good choice, for security systems that use YOLOv8-based Artificial Intelligence to watch things.

[3] **Khin and Htaik** conducted a comparative study between RetinaNet, EfficientDet, and YOLOv8 for gun detection using a custom dataset. Their results demonstrated that YOLOv8 performed better in terms of detection speed and accuracy, especially for real-time surveillance applications.

[4] **Ross Girshick et al.** proposed the R-CNN deep learning architecture for scalable object detection. Their work improved object localization and image classification performance using convolutional neural networks. However, the model required high computational resources and slower processing time compared to YOLO-based systems.

[5] **Verma and Dhillon** developed a hand-held gun detection system using Faster R-CNN deep learning architecture. Their study demonstrated that deep learning-based object detection techniques can improve firearm detection accuracy in surveillance systems.

[6] **Grega et al.** The researchers proposed a system that can automatically find firearms and knives in pictures from security cameras. This system is important for keeping people safe and stopping crimes. The study also talked about some problems they had like when it's really dark or when things are in the way of the security cameras. The firearm and knife detection system is an idea because it can help with public safety and crime prevention and the researchers think that intelligent surveillance systems, like the firearm and knife detection system are really important.

[7] **Sarkar et al.** designed a weapon detection system using Artificial Intelligence and Deep Learning techniques. Their framework focused on automatic weapon recognition and alert generation for modern surveillance applications. The research emphasized the role of AI in reducing manual monitoring efforts.

[8] **Jain et al.** developed a weapon detection framework using Deep Learning and Artificial Intelligence for security applications. Their study demonstrated that convolutional neural networks can effectively detect weapons from surveillance video streams under different environmental conditions.

[9] **González et al.** investigated the challenges of real-time gun detection in CCTV surveillance systems. Their research identified major issues such as false positive detections, crowded scenes, and varying lighting conditions. The study concluded that real-time weapon detection still requires further improvements in accuracy and reliability.

[10] **Li et al.** presented a survey on Convolutional Neural Networks and their applications in computer vision and object detection systems. Their research explained how CNN architectures improved image classification and feature extraction performance in deep learning applications.

[11] **Cao et al.** proposed Pyramid-YOLOv8, an enhanced version of YOLOv8 designed for precise object detection. Their work improved multi-scale feature extraction and enhanced the detection of small and partially hidden objects in complex environments.

[12] **Glenn Jocher**, through the Ultralytics YOLOv8 documentation, explained the architecture, training process, and implementation techniques of YOLOv8 for real-time object detection tasks. The documentation highlighted the advantages of YOLOv8 in terms of speed, scalability, and detection accuracy.

From the reviewed literature, it is observed that Deep Learning and YOLO-based object detection models have significantly improved intelligent surveillance systems and automated weapon detection technologies. However, challenges such as low-light detection, false positives, object occlusion, and crowded environments still require further improvement. Therefore, this research proposes a YOLOv8-based intelligent weapon detection system to achieve accurate and real-time surveillance for enhancing public safety applications.

Problem Statement

The number of crimes and violent incidents is going up fast. This is a problem for public safety and security everywhere in the world. Places like airports, railway stations and shopping malls are very easy to attack. To make these places safer we use surveillance cameras and monitoring systems.. These systems are not perfect because they need people to watch them all the time, which is not very efficient and can lead to mistakes.

Watching surveillance cameras for a time is hard for security people. They can get tired or lose focus. This means they might miss something like a hidden weapon. In areas it is even harder to find threats. So bad things might happen before we can stop them.

The old surveillance systems are not very good. They only record what is happening. They do not tell us if there is a threat now. They cannot find weapons like guns automatically. They do not send alerts to security people away. The old ways of finding objects are not very good either. They are not very accurate they are slow. They can give false alarms. They also do not work well in lighting.

New technology like Deep Learning and Computer Vision has made it easier to find objects.. Many systems still have problems finding weapons in real-time. Some systems need a lot of power and struggle to find weapons. They also do not send alerts fast in emergency situations. Even a short delay can be very bad in high-security areas.

So we need a surveillance system that can find weapons in videos without much help from people. The system should be able to find weapons not give many false alarms and work fast and well in different environments. The main goal of this research is to make a YOLOv8-based weapon detection system that can find weapons quickly and send alerts to make people safer.

The YOLOv8-based weapon detection system is what we are trying to develop. The YOLOv8-based weapon detection system should be able to identify weapons like guns and knives. The YOLOv8-based weapon detection system will help improve safety and security. The YOLOv8-based weapon detection system is very important for places, like airports and shopping malls.

Objectives

The main goal of this research is to create a weapon detection system that uses Artificial Intelligence and the YOLOv8 model to make public places safer. This system will look at video from security cameras to find weapons like guns and knives quickly and accurately. It will also help emergency services respond faster to situations.

The details of what this research wants to do are as follows:

1 Main Objective

To make a system that can automatically find weapons in time using Artificial Intelligence and YOLOv8. This will help keep people safe and make security better at places like airports and schools. The weapon detection system will use Artificial Intelligence to do this.

2 Specific Objectives

2.1 To Make a Real-Time Weapon Detection System

The first goal is to create a system that can look at video and find things like guns and knives. This system will watch the video all the time. Find suspicious things right away. The weapon detection system will be very good at finding weapons.

2.2 To Improve Detection Accuracy

Another important goal is to make sure the weapon detection system is very good at finding weapons. The YOLOv8 model will help the weapon detection system find and classify weapons correctly. This is a part of the research on the weapon detection system.

2.3 To Reduce False Alarms

The weapon detection system should not give alarms. It should balance finding all the weapons with not giving alarms. This is very important for the weapon detection system to work well.

2.4 To Reduce Human Involvement in Surveillance

Surveillance systems need people to watch the video all the time. This research wants to use Artificial Intelligence to automate the process and reduce the workload of security personnel. This will help the security personnel a lot. Make their job easier.

2.5 To Respond Faster in Emergency Situations

The weapon detection system will send alerts if it finds a weapon. This will help emergency services respond faster and prevent things from happening. The Artificial Intelligence system will be very helpful in this. Make a big difference.

2.6 To Make Public Places Safer

One of its goals is to make public places like airports, schools, and shopping malls more secure through surveillance systems. Weapon detection systems will be a part of this and help keep people safe.

2.7 To Improve Detection in Conditions

The weapon detection system should work well even when it is hard to see. There are people and it should also work with different camera angles and when things are moving. The YOLOv8 model will help the weapon detection system with this.

2.8 To Use YOLOv8 for Fast Object Detection

This research will use YOLOv8 because it is very fast and can find objects in time. It is also good at finding features and localizing objects. The YOLOv8 model is a part of the research on the weapon detection system.

2.9 To Make the System Work Better with Different Data

The study will use techniques to make the weapon detection system work better with kinds of data. This will help it find weapons even when the video is not very good. The Artificial Intelligence system will be very good at this. Make the weapon detection system work well.

2.10 To Create a Surveillance Solution

The final goal is to create a system that can be used in life. It should be able to work with existing security cameras and help keep people safe. The weapon detection system will be a help, to security personnel and make their job easier.

If this research is successful it will help create surveillance systems that can improve security reduce crime and make public places safer. This will be done by using Artificial Intelligence and the YOLOv8 model. The weapon detection system will be a part of this and help keep people safe.

Proposed System / Proposed Methodology

The proposed system is a real-time weapon detection system that helps keep people safe. It is designed to improve the way we watch over places. This system uses a tool called YOLOv8 to find things like pistols, rifles and knives in video from CCTV cameras. When it finds a weapon it immediately sends a warning to the people in charge of security so they can act fast.

This system uses things like Artificial Intelligence, Computer Vision and Deep Learning to create a way to watch over places. It can find weapons really fast and accurately without needing people to watch the videos all the time. The proposed system is a real-time weapon detection system that makes people safer.

1. Overview of Proposed System

The proposed weapon detection system has parts that work together to find weapons in time and send warnings. The main parts are:

- Getting video from surveillance cameras
- Breaking the video into pictures
- Making the pictures look better
- Using learning to find things in the pictures
- Using YOLOv8 to find weapons
- Drawing a box around the weapon
- Sending a warning to the security people
- Showing what was found on the screen

It starts with getting video from CCTV cameras. Then it uses the YOLOv8 tool to look at the pictures. If it finds a weapon it draws a box around it. Sends a warning to the people in charge. The proposed system is a way to watch over places and make people safer.

2. System Architecture

The system has parts that work together to find weapons quickly and accurately. The proposed system uses YOLOv8 to find weapons in video from CCTV cameras.

2.1 Input Module

This part gets video from CCTV cameras in places like train stations, airports, schools and shopping malls. It sends the pictures to the part for analysis. The proposed system is designed to make people safer.

2.2 Preprocessing Module

This part makes the pictures look better before sending them to the deep learning tool. It does things like making the pictures smaller reducing noise making the pictures brighter making the pictures clearer and normalizing the pictures. The proposed system uses YOLOv8 to find weapons.

2.3 Feature Extraction Module

This part uses a kind of network to find important things in the pictures like edges and shapes. The YOLOv8 tool learns these things on its own when it is trained. The proposed system is a real-time weapon detection system.

2.4 Weapon Detection Module

This is the part of the system. It uses the YOLOv8 tool to look at each picture and find weapons. It does things like finding where the weapon is drawing a box around the weapon figuring out how sure it is and identifying what kind of weapon it is. The proposed system can find kinds of weapons including pistols, rifles and knives.

3. Working of Proposed System

Here is how the proposed system works:

Step 1: Getting Video

The system gets video from surveillance cameras in places.

Step 2: Breaking into Pictures

The video is broken into pictures for analysis.

Step 3: Making Pictures Look Better

The pictures are made to look and are prepared for the YOLOv8 tool.

Step 4: Finding Important Things

The YOLOv8 tool finds things in the pictures like edges and shapes.

Step 5: Finding Weapons

The tool finds weapons in the pictures. Figures out what kind of weapon it is.

Step 6: Reducing False Warnings

The system reduces warnings by using techniques.

Step 7: Sending Warnings

If a weapon is found the system sends a warning to the security people.

Step 8: Showing What Was Found

The system shows what was found on the screen with a box around the weapon and a label. The proposed system is a way to watch over places.

4. Advantages of Proposed Methodology

The proposed system has advantages over surveillance systems. It can find weapons in time. It sends warnings quickly. It is very accurate. It does not need people to watch the videos all the time. It makes people safer. It can identify threats automatically. It can be easily added to existing CCTV systems. It is good at watching over places. The proposed system is a real-time weapon detection system that uses the YOLOv8 tool to find weapons in video, from CCTV cameras. The proposed system is designed to make people safer and to improve the way we watch over places.

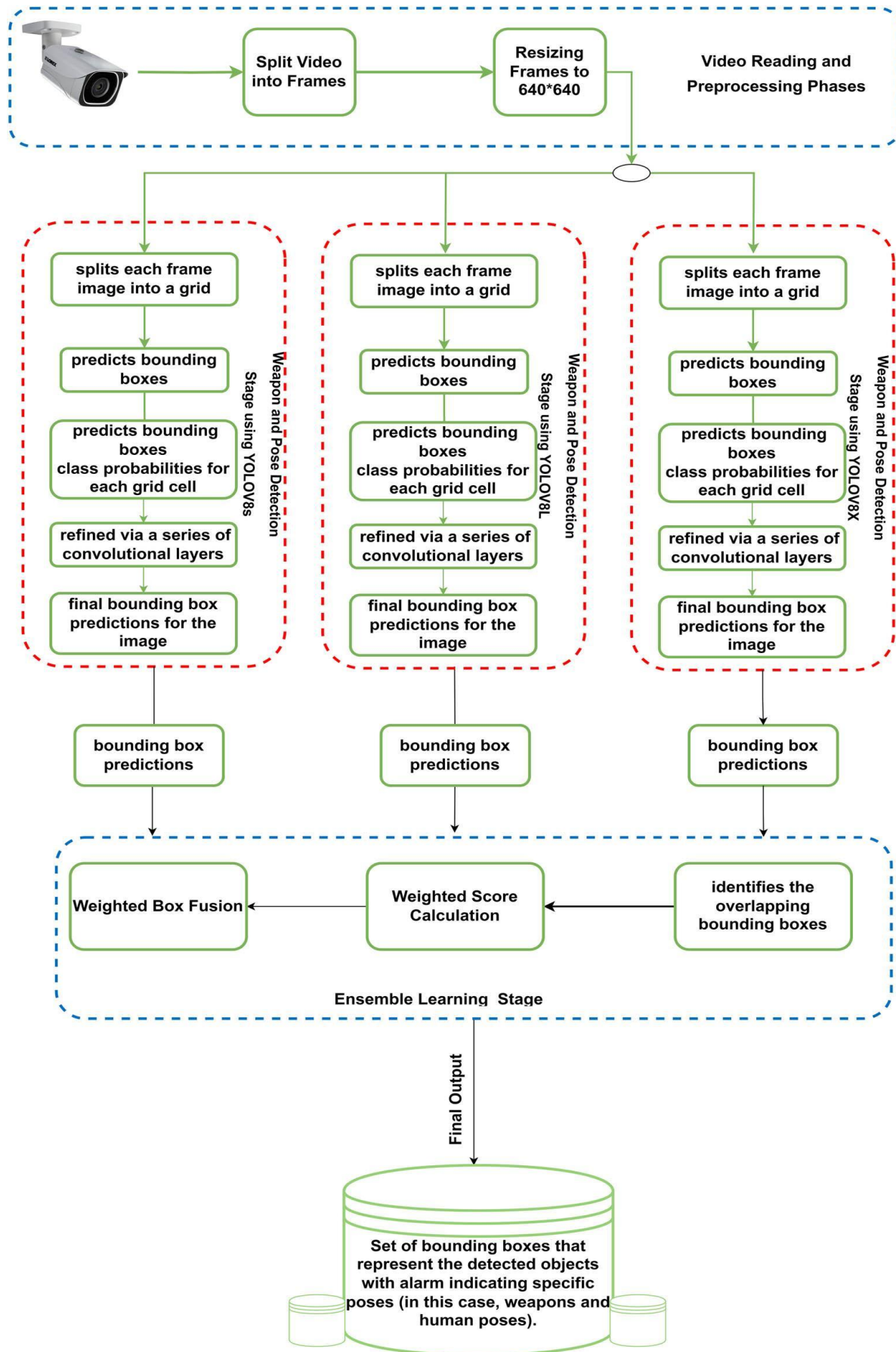


Fig. 1. Architecture and Workflow of the Proposed YOLOv8-Based Real-Time Weapon Detection System

Methodology

The way we plan to do this is by creating a system that can find weapons quickly using a learning model called YOLOv8. This system has a stages: we collect data get the images ready make the data better train the YOLOv8 model find weapons and see how well it works. Each stage is designed to make the system good and work well.

The main goal of the YOLOv8 model system is to find weapons in places like airports, railway stations, schools, shopping malls, banks and other areas to make people safer and more secure.

1. Collecting Data

To make a weapon detection system we need to collect a lot of data. We need a set of data to train the YOLOv8 model properly.

The data set has pictures of types of weapons like:

- Pistols
- Rifles
- Revolvers
- Knives
- Sharp objects
- Things that are not weapons
- We get these pictures from places including:
 - Open-source datasets
 - Online image repositories
 - CCTV surveillance samples
 - Public computer vision datasets
- The data set has pictures taken in places like:
 - Inside and outside
 - At night
 - In not crowded places
 - From angles and distances

We label each picture by drawing boxes around the weapons and giving them names. This helps the YOLOv8 model learn what things are and where they are when it is being trained.

2. Getting Images Ready

Before we train the YOLOv8 model we make all the pictures the same size and quality.

To get the pictures ready we do things like:

- Make all the pictures 640×640 pixels
- Make the pictures look the same
- Remove noise
- Make the pictures brighter
- Make the pictures clearer

Making the pictures look the same helps the YOLOv8 model train faster and work better.

3. Making Data Better

We use techniques to make the data set more interesting and help the YOLOv8 model work well in different real-life situations.

These techniques include:

- Rotating pictures

- Making objects bigger or smaller
- Flipping pictures sideways
- Changing pictures randomly

These techniques help the YOLOv8 model find weapons from angles, directions and distances.

4. The YOLOv8 Model

We choose the YOLOv8 model because it is fast and good at finding things.

The YOLOv8 model has three parts:

- The backbone
- The neck
- The detection head

The backbone looks at the pictures and finds things like edges, textures, patterns and shapes using layers.

The neck combines the things it finds to help the YOLOv8 model work better at finding things.

The detection head says what it thinks the thing is, where it is and how sure it is.

The YOLOv8 model can find weapons quickly and accurately in real-life situations.

5. Training the Model

We train the YOLOv8 model using the data set we made and the best settings.

To train the YOLOv8 model we do things like:

- Load the training data
- Look at the data
- Calculate the loss
- Change the weights
- Check the results

We use algorithms like Adam Optimizer and Stochastic Gradient Descent to make the YOLOv8 model better and reduce mistakes.

6. Using the Model in Real-Life

After we train the YOLOv8 model we use it to watch things in time.

To use the YOLOv8 model in time we do things like:

- Watch video streams
- Take pictures from the video
- Use the YOLOv8 model to find things
- Identify weapons
- Remove detections
- Draw boxes around the things we find
- Send alerts

The YOLOv8 model system works fast and accurately making it good for watching things in time.

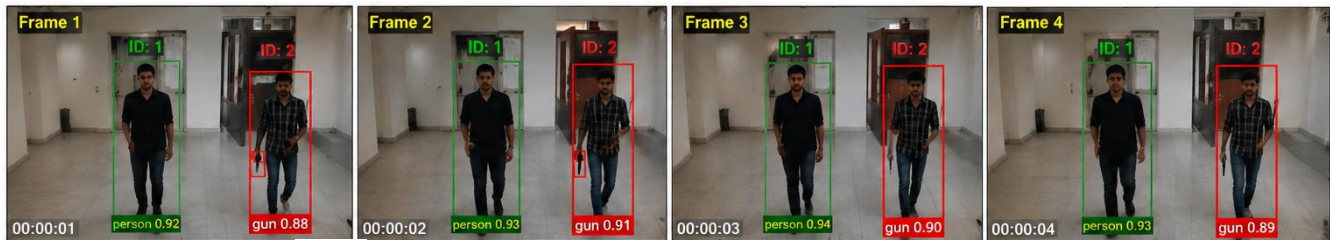
7. Sending Alerts

When the YOLOv8 model finds a weapon it sends an alert to the security people.

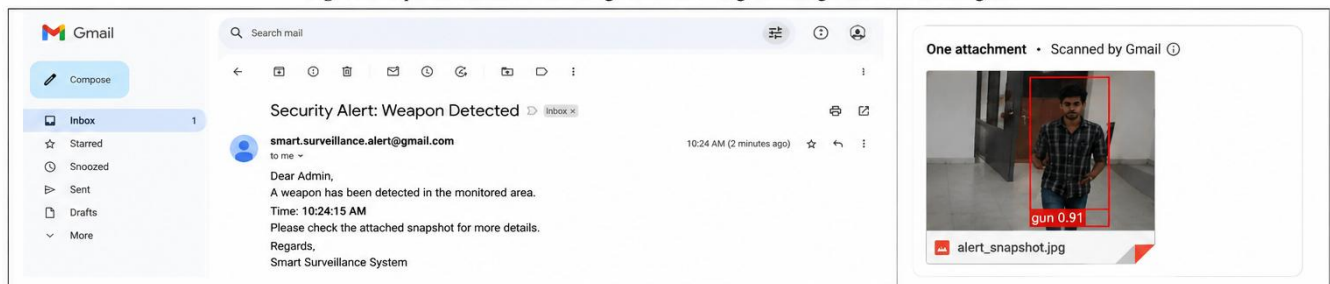
The alert system includes:

- Warning messages
- Pictures of the weapons we find
- Details about what we find and how sure we're
- A way to watch things in time

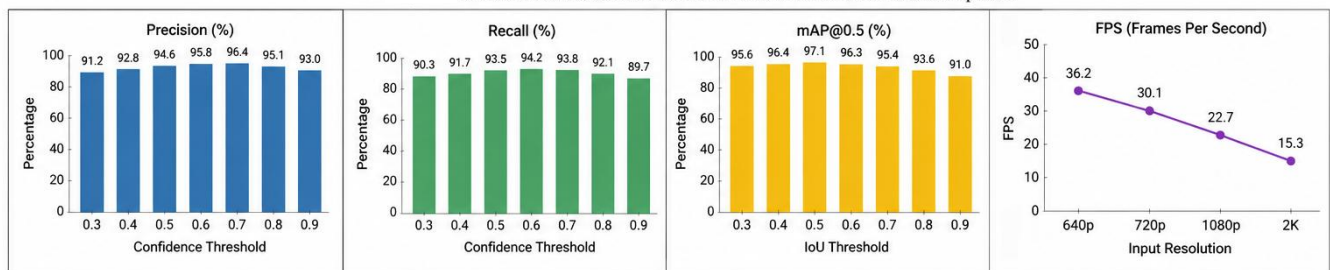
This helps the security people react quickly and makes people safer, by letting them act fast when they find something that might be a threat.



Sample detection and tracking results showing bounding boxes and tracking IDs.



Screenshot of the automated email alert with attached threat snapshot.



Performance graphs for precision, recall, mAP, and FPS.

Fig. 2. Overall results of the proposed AI-based weapon detection and alert system showing real-time object tracking, automated email notification, and performance evaluation metrics.

Mathematical Model / Equations

The mathematical model of the proposed AI-based weapon detection system defines the calculations and algorithms used for image preprocessing, object detection, model training, and performance evaluation. These mathematical equations help the YOLOv8 deep learning model accurately detect weapons, localize objects, and classify them efficiently in real-time surveillance systems.

The proposed weapon detection system uses mathematical operations in several stages including image normalization, bounding box prediction, confidence score calculation, loss optimization, and performance evaluation.

1. Image Normalization

Before feeding images into the YOLOv8 model, image normalization is performed to improve training stability and convergence speed.

The normalization equation is:

$$I' = \frac{I - \mu}{\sigma}$$

Where:

- I = Original image pixel value
- I' = Normalized image
- μ = Mean pixel value
- σ = Standard deviation

Normalization helps maintain consistent pixel distributions and improves model performance.

2. Bounding Box Representation

The YOLOv8 model represents detected objects using bounding boxes.

$$B = (x, y, w, h)$$

Where:

- x = x-coordinate of box center
- y = y-coordinate of box center
- w = Width of the bounding box
- h = Height of the bounding box

These parameters define the position and size of detected weapons in the image.

3. Confidence Score Calculation

The confidence score indicates how certain the model is about detecting an object.

$$C = P(\text{Object}) \times IoU$$

Where:

- C = Confidence score
- $P(\text{Object})$ = Probability that an object exists
- IoU = Intersection over Union value

Higher confidence values indicate stronger detection certainty.

4. Intersection over Union (IoU)

Intersection over Union (IoU) measures the overlap between the predicted bounding box and the ground truth bounding box.

$$IoU = \frac{\text{Area of Overlap}}{\text{Area of Union}}$$

Where:

- Area of Overlap = Common area between predicted and actual boxes
- Area of Union = Total combined area of both boxes

IoU values range between 0 and 1. Higher IoU values indicate better localization accuracy.

5. Rotation Transformation

Rotation transformation is used during data augmentation to improve detection from different viewing angles.

$$R(\theta) = \begin{bmatrix} \cos \theta & -\sin \theta \\ \sin \theta & \cos \theta \end{bmatrix}$$

The transformed coordinates are calculated as:

$$X' = R(\theta)X$$

Where:

- θ = Rotation angle
- X = Original coordinates
- X' = Rotated coordinates

This transformation helps the model recognize weapons from multiple orientations.

6. Scaling Transformation

Scaling is used to resize images while preserving object proportions.

$$I' = s \times I$$

Where:

- I = Original image
- I' = Scaled image
- s = Scaling factor

Scaling improves detection performance for objects at different distances and sizes.

7. Loss Function

YOLOv8 uses a combined loss function to optimize detection performance.

$$L = L_{box} + L_{obj} + L_{cls}$$

Where:

- L_{box} = Bounding box regression loss
- L_{obj} = Object confidence loss
- L_{cls} = Classification loss

The loss function helps improve:

- Bounding box accuracy
- Confidence prediction

- Weapon classification performance

8. Weight Update Equation

During training, model weights are updated using backpropagation and gradient descent optimization.

$$W_{new} = W_{old} - \eta \frac{\partial L}{\partial W}$$

Where:

- W_{old} = Current weights
- W_{new} = Updated weights
- η = Learning rate
- $\frac{\partial L}{\partial W}$ = Loss gradient

This process minimizes prediction error during training.

9. Precision

Precision measures the proportion of correctly detected weapons among all detections.

$$Precision = \frac{TP}{TP + FP}$$

Where:

- TP = True Positives
- FP = False Positives

Higher precision indicates fewer false alarms.

10. Recall

Recall measures the ability of the model to detect all actual weapons.

$$Recall = \frac{TP}{TP + FN}$$

Where:

- FN = False Negatives

Higher recall indicates better threat detection capability.

11. F1-Score

F1-Score balances precision and recall.

$$F1 = 2 \times \frac{Precision \times Recall}{Precision + Recall}$$

A higher F1-score indicates better overall model performance.

12. Mean Average Precision (mAP)

Mean Average Precision (mAP) is a standard evaluation metric for object detection models.

$$mAP = \frac{1}{N} \sum_{i=1}^N AP_i$$

Where:

- AP_i = Average Precision of class i
- N = Total number of classes

Higher mAP values indicate better detection accuracy.

13. Non-Maximum Suppression (NMS)

Non-Maximum Suppression removes duplicate bounding boxes and keeps only the best prediction.

$$NMS(B, S) = \arg \max (S)$$

Where:

- B = Set of bounding boxes
- S = Confidence scores

NMS improves final detection quality and reduces redundant predictions.

Algorithms Used

AI-based weapon detection systems use Deep Learning and Computer Vision algorithms to detect dangerous weapons from surveillance video streams in real-time. The system mainly uses the YOLOv8 object detection algorithm along with Convolutional Neural Networks (CNNs) to achieve high detection accuracy and fast processing speed.

The selection of these algorithms is important because the overall performance of the surveillance system depends on detection processing speed, accuracy, and real-time response capability.

1. Convolutional Neural Network (CNN)

Convolutional Neural Networks (CNNs) are deep learning models widely used for image processing and object recognition tasks. In the proposed system, CNNs are used like the backbone of the YOLOv8 architecture for:

- Feature extraction
- Object recognition
- Pattern learning
- Weapon classification
- CNNs process images through multiple layers such as:
- Convolution layers
- Pooling layers
- Activation layers
- Fully connected layers

These layers help the model learn important visual features including edges, shapes, textures, and object patterns.

The convolution operation is represented as:

$$F(i,j) = \sum_m \sum_n I(i-m, j-n) K(m,n)$$

Where:

- (I) = Input image
- (K) = Kernel or filter
- (F) = Extracted feature map

CNNs improve the ability of the model to identify weapons from complex surveillance environments.

2. YOLO (You Only Look Once)

YOLO is a real-time object detection algorithm used in computer vision applications. It performs object localization and classification simultaneously in a single forward pass.

The main advantages of YOLO include:

- High processing speed
- Real-time detection capability
- Computational efficiency
- Multi-object detection

YOLO divides the input image into grids and predicts:

- Bounding boxes
- Confidence scores
- Object class probabilities

The confidence score is calculated as:

$$\text{Confidence} = P(\text{Object}) \times \text{IoU}$$

YOLO is highly suitable for surveillance systems because it can process video frames quickly with low latency.

3. YOLOv8 Algorithm

YOLOv8 is the latest version of the YOLO family and serves as the primary algorithm in the proposed weapon detection system. It provides improvements in:

- Detection accuracy
- Feature extraction
- Real-time inference
- Small object detection
- Computational optimization

The YOLOv8 architecture consists of:

1. Backbone Network
2. Neck Network
3. Detection Head

Working Principle of YOLOv8

The working process of YOLOv8 includes the following stages:

1. Input surveillance frame to the model
2. Extract visual features using CNN backbone
3. Aggregate features using Feature Pyramid Networks (FPN)

4. Predict bounding boxes for detected objects
5. Classify detected objects into weapon categories
6. Apply Non-Maximum Suppression (NMS) to remove duplicate detections

YOLOv8 performs real-time detection with high accuracy and efficiency.

4. Non-Maximum Suppression (NMS)

Non-Maximum Suppression (NMS) is a post-processing algorithm used to remove duplicate overlapping detections.

NMS improves:

- Detection quality
- Prediction accuracy
- Bounding box optimization

The NMS operation keeps only the bounding box with the highest confidence score.

5. Adam Optimizer

The Adam optimization algorithm is used during model training to update network weights efficiently.

Adam combines:

- Momentum optimization
- Adaptive learning rates

The weight update equation is:

$$W_{t+1} = W_t - \eta \nabla L(W_t)$$

Where:

- W_t = Current weights
- W_{t+1} = Updated weights
- η = Learning rate
- $\nabla L(W_t)$ = Loss gradient

Adam helps improve convergence speed and training stability.

6. Data Augmentation Techniques

Data augmentation techniques are applied to improve model robustness and generalization capability.

The augmentation methods include:

- Rotation
- Scaling
- Flipping
- Brightness adjustment
- Contrast enhancement
- Noise injection

Rotation transformation is represented as:

$$R(\theta) = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}$$

These techniques help the model perform effectively under different lighting conditions, camera angles, and environmental variations.

7. Algorithm Flow of Proposed System

The overall workflow of the proposed weapon detection system is as follows:

1. Capture live video stream from CCTV camera
2. Extract video frames
3. Preprocess input images
4. Apply YOLOv8 for feature extraction
5. Detect weapons using object detection layers
6. Predict bounding boxes and confidence scores
7. Apply Non-Maximum Suppression
8. Classify detected weapons
9. Generate alert notifications
10. Display output with bounding boxes and labels

8. Advantages of YOLOv8 over Other Algorithms

Algorithm	Speed	Accuracy	Real-Time Detection	Complexity
R-CNN	Slow	High	No	High
Faster R-CNN	Moderate	Very High	Limited	High
SSD	Fast	Moderate	Yes	Moderate
YOLOv8	Fast	High	Yes	Efficient

YOLOv8 provides an effective balance between:

- Detection speed
- Accuracy
- Computational efficiency
- Real-time performance

Experimental Setup

The setup for the weapon detection system has all the parts it needs to find weapons and watch what is going on in real time. This system uses ways of learning and seeing things like Deep Learning and Computer Vision to find things. The YOLOv8 model is used to find weapons like pistols and rifles and knives in videos from security cameras.

The place where we test this system is made to work in time to train the system quickly and to find weapons correctly. The system is made to detect weapons, like pistols and rifles and knives.

1. Hardware Requirements

The system we are talking about needs good hardware to work properly. This means it needs to be able to process things smoothly do calculations fast and keep an eye on things in real time.

What The Hardware Should Be :

Processor: We need an Intel Core i7 or an AMD Ryzen 7

RAM: We need 16 GB of memory or more

GPU: We need a graphics card, from NVIDIA called an RTX Series GPU

Storage: We need a fast storage drive that's at least 512 GB and it should be a solid state drive

Camera: We can use a CCTV Camera or an IP Camera or even a simple Webcam

Operating System: The system should run on Windows 10 or Linux

Role of Hardware Components :

1. Processor (CPU)

The processor controls the overall operation of the system. It performs tasks such as frame extraction, preprocessing, and system management. A high-speed processor improves system performance and reduces processing delay.

2. Graphics Processing Unit (GPU)

The GPU plays an important role in deep learning model training and real-time inference. It performs parallel computations required for YOLOv8 operations and accelerates model execution.

Functions of GPU include:

- Fast matrix computations
- Real-time object detection
- Deep learning model training
- Faster image processing

3. Memory (RAM)

You need a lot of memory to load data and process videos and other things. More memory means your system is more stable and you can do things at the same time. You can load datasets. Do deep learning operations when you have a lot of memory. Learning operations and loading datasets require a lot of memory.

4. Storage

SSD storage provides faster data access and improves dataset loading speed, model saving, and file management. The storage system is used to store:

- Training datasets
- Trained models
- Surveillance recordings
- Detection results

2. Software Requirements

Various software tools and libraries are used for model development, training, image processing, and visualization.

Software Specifications

Software / Tool	Purpose
Python	Programming Language
YOLOv8	Object Detection Framework
OpenCV	Image and Video Processing
PyTorch	Deep Learning Framework
NumPy	Numerical Computation
Pandas	Data Handling
Matplotlib	Data Visualization
Google Colab / Jupyter Notebook	Training Environment
LabelImg	Image Annotation Tool

3. Programming Language

Python

Python is used as the primary programming language because of its:

- Simple syntax
- Large AI ecosystem
- Extensive library support
- Easy implementation of deep learning models

Python supports integration with:

- OpenCV
- PyTorch
- YOLOv8
- NumPy
- TensorFlow

4. Deep Learning Framework

PyTorch

PyTorch is used for implementing and training the YOLOv8 deep learning model.

Advantages of PyTorch

- Dynamic computation graphs
- GPU acceleration support
- Easy debugging
- Flexible neural network architecture

PyTorch helps in:

- Building neural networks
- Tensor operations
- Model optimization
- Deep learning training

5. Computer Vision Library

OpenCV

OpenCV is used for image processing and real-time video analysis.

Functions Performed Using OpenCV

- Capturing video streams
- Frame extraction
- Image preprocessing
- Real-time visualization
- Image resizing
- Noise filtering
- Bounding box drawing
- Video frame processing

6. Dataset Preparation

A high-quality dataset is required for training the YOLOv8 weapon detection model. The dataset preparation process includes:

- Collecting weapon images
- Image annotation
- Data preprocessing
- Dataset splitting

The dataset is divided into:

70% Training Data

20% Validation Data

10% Testing Data

Proper dataset preparation improves model accuracy and detection performance.

7. Annotation Tool

LabelImg

LabelImg is used for annotating weapon images in the dataset. Bounding boxes are manually drawn around weapons, and labels are assigned to each object.

Functions of LabelImg

Bounding box annotation

Class labeling

Annotation export in YOLO format

Dataset preparation for training

Accurate annotation improves model learning and detection accuracy.

8. Model Training Setup

The YOLOv8 model is trained using optimized hyperparameters for better detection performance.

Training Parameters

Parameter	Value
Epochs	50 – 100
Batch Size	16
Learning Rate	0.001

9. Training Process

The training process of the proposed system has a lot of steps.

Here is what the proposed system does when it is training:

Step 1 is Dataset Loading.

The proposed system loads the annotated dataset into the place where it trains.

Step 2 is Image Preprocessing and Augmentation.

The proposed system makes the images smaller. It also makes them look more normal.

It even adds images to the dataset to make the model better at finding things.

Step 3 is Model Initialization.

The proposed system starts with the YOLOv8 weights that it learned before.

Step 4 is Forward Propagation.

The proposed system looks at the images. Tries to find what is in them.

Step 5 is Loss Calculation.

The proposed system sees how wrong its guesses are.

It calculates the difference between what's really in the images and what the proposed system thinks is, in the images.

Step 6 is Backpropagation.

The proposed system changes the weights to make its guesses better.

Step 7 is Weight Optimization.

The proposed system makes the weights even better so it can find things accurately in the images.

The proposed system does all this to make the detection accuracy of the proposed system better.

Step 8: Validation

The trained model is validated after each epoch to evaluate performance.

10. Real-Time Testing Environment

The trained YOLOv8 model is tested using:

- CCTV video streams

- Recorded surveillance videos
- Webcam input streams

The system performs:

- Real-time frame processing
- Weapon detection
- Bounding box generation
- Confidence score prediction
- Alert notification generation

11. Performance Evaluation Metrics

The performance of the proposed system is evaluated using standard object detection metrics.

Precision

$$Precision = \frac{TP}{TP + FP}$$

Recall

$$Recall = \frac{TP}{TP + FN}$$

F1-Score

$$F1 = 2 \times \frac{Precision \times Recall}{Precision + Recall}$$

Mean Average Precision (mAP)

$$mAP = \frac{1}{C} \sum AP_c$$

These metrics evaluate:

- Detection accuracy
- Localization quality
- Classification performance
- Real-time efficiency

12. Advantages of Experimental Setup

The proposed experimental setup provides several advantages:

- Faster model training using GPU acceleration
- Real-time surveillance monitoring
- Accurate weapon detection
- Reduced manual monitoring effort
- Improved public safety

- Scalable deployment capability
- Easy integration with CCTV systems
- Efficient real-time alert generation

Advantages of Proposed System

The proposed weapon detection system that uses the YOLOv8 algorithm is an efficient way to keep an eye on things in real time and keep people safe. This system combines Deep Learning and Computer Vision to detect weapons from video streams and send out alerts right away. The proposed system has advantages, including:

1. High Detection Accuracy

The YOLOv8 algorithm is very good at finding objects. Can tell things apart correctly. It finds weapons accurately. Reduces mistakes making the system more reliable.

2. Faster Processing Speed

The system looks at video frames quickly which makes it good for watching things in real time. The YOLOv8 algorithm is designed to find objects and analyze video efficiently.

3. Automatic Alert Generation

When the system finds a weapon it sends a warning to security people away. This warning can include a message, a picture of what was found and where it was found so they can react quickly.

4. Reduced Human Dependency

The system does not need people to watch it all the time. This reduces mistakes that people might make because they are tired, distracted or slow to react.

5. Real-Time Weapon Detection

The proposed system can find weapons like pistols, rifles and knives from CCTV video streams as they happen. This helps security people react quickly to threats and take action right away.



Fig. 3. Real-Time Weapon Detection Using YOLOv8 in CCTV Surveillance

6. Improved Public Safety

The proposed system makes public places like airports, schools, and Railway stations, safer by finding threats before something bad happens.

7. Efficient Performance in Complex Environments

The system works well even when things are tough like:

- When it is dark
- When there are a lot of people around
- When the video is blurry
- When the camera is at an angle

This makes the system more reliable when it is used in the real world.

8. Scalability and Flexibility

The proposed system can be easily added to existing CCTV systems and smart city setups. It can be used in different places without needing a lot of changes to the hardware.

9. Reduced False Alarms

The YOLOv8 algorithm uses a confidence score to reduce warnings and incorrect findings. This makes the system more efficient and trustworthy.

10. Cost-Effective Surveillance Solution

The automated system reduces the need for a lot of security people to watch things all the time. This makes the system more cost-effective and efficient, for a time.

Overall Benefits of the Proposed System

The proposed system that uses YOLOv8 has benefits, including:

- Finding threats in time
- Being able to react
- Finding weapons accurately
- Watching things automatically
- Keeping people safer
- Reducing costs
- Being able to be used in different places

Applications

Applications The AI-based weapon detection system using YOLOv8 is useful in safety and security places where monitoring and threat detection happen in real-time. This system helps surveillance teams work better respond faster and prevent incidents involving weapons through automated monitoring.

Applications of Proposed System

1. Airport Security

The weapon detection system can help in airports to keep an eye on passengers and find weapons in areas that're not open to the public. This makes passengers safer. Improves how secure airports are.

2. Railway Stations

Railway authorities can use the system to watch platforms and see if anything suspicious or weapons appear in time. This keeps people safer at railway stations.

3. Schools and Colleges

The system can make schools and colleges safer by finding weapons and stopping incidents, on campus. This helps keep students and staff

4. Smart City Surveillance

The weapon detection system can work with city surveillance projects to monitor and manage security automatically using AI.

5. Military and Defense Applications

The system can help military and defense organizations watch areas and find unauthorized weapons or threats right away. The weapon detection system is very helpful here. The military can use it to improve their security

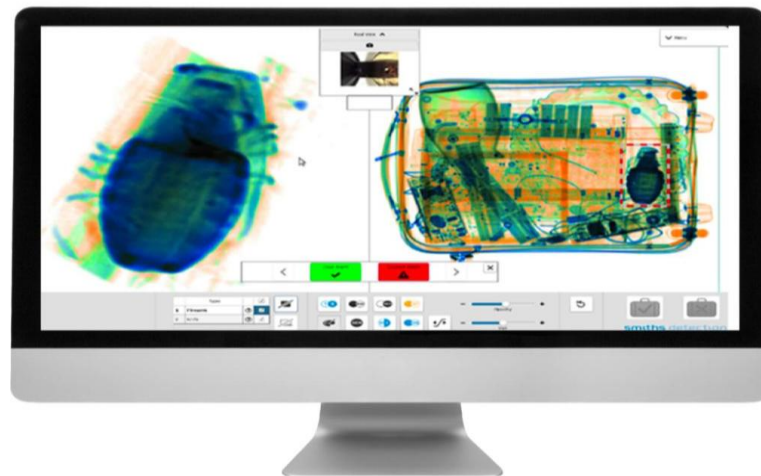


Fig. 4. Application of YOLOv8-Based Weapon Detection System in Public Safety Surveillance

Challenges and Limitations

The YOLOv8-based weapon detection system I am talking about can detect weapons accurately and in time but there are still some challenges and limitations that can affect how well the YOLOv8-based weapon detection system works in the real world.

Limitations of the Proposed YOLOv8-based Weapon Detection System

1. Problems with Light

The YOLOv8-based weapon detection system may not work as well in low light or dark places. When it is hard to see the pictures are not as clear and the YOLOv8-based weapon detection system has a time detecting weapons from the video.

2. Finding Objects

It is hard to detect small weapons that are far away from the camera. Small things do not have much detail so the YOLOv8-based weapon detection system may not be able to detect them correctly.

3. When Objects are Blocked

Sometimes weapons are hidden behind people or other things. This makes it hard for the YOLOv8 model to find and identify the weapons correctly.

4. Complex Scenes with People

In places with a lot of people and things it can be hard for the YOLOv8-based weapon detection system to find weapons in the video.

5. Wrong Predictions

The YOLOv8-based weapon detection system can make mistakes sometimes:

It can say something is a weapon when it is not or it can miss a weapon.

These mistakes can make the YOLOv8-based weapon detection system less reliable.

6. Need for Computers

The YOLOv8-based weapon detection system needs strong computers with good graphics cards a lot of memory and fast processors to work well. This can make it expensive to set up.

7. Need for Good Data

The YOLOv8 model needs a lot of pictures of weapons to learn from. Collecting and labeling these pictures can take a time and be difficult.

8. Processing Videos, at the Same Time

If the YOLOv8-based weapon detection system has to look at many videos at the same time it can get slowed down. The YOLOv8-based weapon detection system needs computers to work in real time.

Future Scope

The YOLOv8-based weapon detection system that we are talking about can be made better by adding new technologies and smart ways of watching things. What we can do in the future is make the system find things accurately work in real time and be used on a big scale.

1. Using Thermal Cameras

Using cameras can make the YOLOv8-based weapon detection system work better when it is dark or there is not much light. Thermal cameras can see things when we cannot so the system will be more reliable.

2. Watching From The Air With Drones

We can use the YOLOv8-based weapon detection system with drones to watch things from the air. This can be useful for things like

- public events
- Keeping borders
- Military operations
- Managing disasters

Using drones to watch things can cover area and make security better.

3. Making Things Work Faster On Simple Devices

We can put the YOLOv8-based weapon detection system on devices like

- Raspberry Pi
- NVIDIA Jetson

This can make the system work faster in real time reduce delays and find things faster when we are watching things live.

4. Working With Face Recognition

If we combine the YOLOv8-based weapon detection system with face recognition we can find people who might be suspicious and make the system smarter, at finding threats. This can make the system more secure and work better.

5. Working With Smart City Surveillance

We can put the YOLOv8-based weapon detection system into the city surveillance system so that we can watch everything from one place and stop crimes automatically. This can make people safer. Help the city work smarter.

Conclusion

This research paper is about a system that uses Artificial Intelligence to detect weapons on time. The system uses a model called YOLOv8 to look at video streams from CCTV cameras and find weapons like pistols, rifles and knives.

The YOLOv8 model helps the system find weapons quickly and accurately in areas. When the system finds a weapon it sends an alert to security personnel. This helps them respond faster. Makes the whole system more effective.

The system has advantages over traditional surveillance systems. These include:

- Detecting weapons on time
- Being very accurate
- Helping security personnel respond faster
- Automatically sending alerts
- Not needing humans to watch the cameras all the time
- Being good at monitoring surveillance video
- Helping to keep people safe
- Being easy to add to existing CCTV systems

The Artificial Intelligence system was tested and it worked well. It could detect weapons in video streams. The system uses computer hardware to make it work faster.

However the system is not perfect. It can have trouble detecting weapons in light. It also needs a lot of computer power to work. The system needs a dataset to learn from so it can get better at detecting weapons and YOLOv8 model.

In the future the Artificial Intelligence system can be improved. It can use technologies like imaging cameras. The system can also be used in cities to help with security and detect weapons.

Overall the research shows that using Artificial Intelligence and YOLOv8 model to detect weapons can make a difference in keeping people safe. The system is a solution, for making security systems.

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