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# A Review of YOLO Object Detection Model in Forensic Evidence Analysis

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**Abstract -** The rate of crimes is an ever-increasing problem in our society. A huge number of cases are still pending and need to be solved. Collecting and analysing evidence is becoming a more important complex task. And it is becoming brain storming thing for officers.

With the availability of enormous data and the need for computer vision systems, research on object detection models/algorithms has become crucial over the last few decades. With various CNN architectures available, the state-of-the-art You Look Only Once (YOLO) model is very popular for many reasons mainly fast detection even on low-end devices.

Followed by introduction and background this paper reviews the innovative and descriptive approach YOLO takes at object detection and how it is helpful in Forensic Evidence Detection and Analysis.

***Key Words***: YOLO, Forensic Evidence, Object Detection, Crime Scene

## 1. INTRODUCTION

Human eye is the world's best camera sensor with 576 mega pixels of resolution and a brain as processor with huge processing power. So human eye is capable of quickly and accurately identifying a given visual data, human made systems with computer-vision enabled are relatively slow and also low in accuracy. Any advancements and research leading to improvements in efficiency and performance in this field could open the paths to create more intelligent and efficient systems, like humans [1]. This research would make human work easy through systems such assistive systems like ADAS [2] [4] in car, in this system driver is assisted for emergency braking by precisely detecting object in front of car. If any object like other vehicle or any animal or human comes in front of car then ADAS will detect and apply emergency brakes. Another example of assistive system is forensic evidence analysis, this system makes forensic expert's work easy by helping in real time evidence detection. Therefore the need of real-time object detection system is highly required to make human task easy. Computer vision as well as object detections are important fields under artificial intelligence.

With availability of huge data on internet and mobile devices accessible to everyone along with this millions of images on internet and cloud. Usage of artificially intelligent systems to utilize this information and make perfect prediction and process the data is necessary because of imperfect performance by humans to perform same tasks [3] [1]. The recognition process is very hard to be performed with traditionally programmed computer algorithms. Different techniques has been proposed to solve the problems and issues in object detection and identification. These techniques focus on various stages viz. recognition, classification, localization, detection etc. factors such as light intensity, quality of image/video, brightness also contributes to complexity of object detection. With continuous progress in these technologies over the past years these techniques has been facing challenges like output accuracy, resource cost as image processing needs high end hardware, processing speed, complexity, quality of datasets etc. with invention of first ever convolutional neural network (CNN) in the 1990s inspired by the Neocognitron [5] and significant inventions like AlexNet which on the ImageNet [6] large scale visual recognition.

Even though these algorithms have made various improvements over period of time, finding multiple objects in images was still an issue. To solve this problem R-CNN algorithm were introduced. Even though R-CNN was comparatively high in accuracy with previous algorithms, it uses too much space and time to detect to overcome this problems Faster R-CNN [6] were introduced. Later need of real time, high speed, and algorithm that can run on low end devices become more important and state-of-the-art real time You Look Only Once YOLO model were introduced.

In recent years the field of forensic science has improved remarkably. New colleges were started teaching forensic science courses. It might be because of increased crime rate in our society. With availability huge crime scene data, pending cases, document frauds, cyber frauds, missing evidence from CCTV footage, mobile clips etc. has forced forensic science to take help of computerized object detection/analysis systems. As traditional methods of forensic evidence analysis are time consuming and sometimes inefficient and heavily dependent on skilled human expertise. YOLO, with its ability of detecting objects within images and videos in real time with speed and accuracy, has become game changer object detection model in the field of forensic science evidence analysis, evidence detection and investigations.

This review paper provides detailed information of You Look Only Once YOLO object detection model and its application in the field of Forensic evidence analysis.

## 2. YOLO

### 2.1 Introduction

You Look Only Once YOLO is state-of-the-art object detection and image segmentation model. It was developed by Joseph Redmon and Ali Farhadi at the University of Washington. It was launched in 2015 [7], YOLO quickly gained its popularity because of its high speed detection and accuracy. After this first release from YOLO further updated models released as follows,

### 2.2 In short introduction to YOLO versions

YOLOv2 released in 2016 with improvement in original model by adding batch normalization, anchor boxes, two stage training and dimension clusters [7] [8].

YOLOv3 was released in 2013 with more efficient backbone network multiple anchors and spatial pyramid pooling. Multi scale detection by using FPN [7] [8] [9].

YOLOv4 was launched in April 2020, this release introduced mosaic data augmentation, a new anchor free detection head, and a new loss function [7] [9].

YOLOv5 released in June 2020. Just after few months of launching YOLOv4 model YOLOv5 launched with improved performance and added new features like hyper parameter optimization, integrated experiment tracking and automatic exports to popular formats. This version provides Flexible control over model size, application of hard wish activation function, and data enhancement [7] [8] [10].

YOLOv6 was launched in 2022 and it was open sourced by Meituan and it is used by many companies in autonomous delivery robots. This model introduces enhancements on its architecture and training scheme, including the implementation of a Bi-directional Concatenation module, an anchor-aided training strategy, and an improved backbone and neck design for state-of-the-art accuracy on the COCO dataset [7] [11].

YOLOv7 was released in July 2022 includes additional tasks like pose estimation on the COCO key points dataset [7].

YOLOv8 is the latest version launched by Ultralytics in Jan 10 2023. As a cutting-edge, state-of-the-art (SOTA) model, YOLOv8 builds on the success of previous versions, introducing new features and improvements for enhanced performance, flexibility, and efficiency. YOLOv8 supports a full range of vision AI tasks, including detection, segmentation, pose estimation, tracking, and classification [7] [12].

YOLO has improved its performance and detection accuracy from 2015-2023 and today we have state of the art YOLO v8 model. It represents ground breaking approach to real-time object detection in digital images and video streams. Unlike traditional object detection methods that rely on multiple passes through the image, YOLO performs detection in a single pass, making it incredibly fast and suitable for real-time applications. Some of the main characteristics of YOLO are its ability to continuously predict the bounding boxes and detect class of objects within an image. YOLO object detection model divides the image into a grid. This system is better in terms of speed and efficiency, while still maintaining impressive accuracy. YOLO has undergone several versions and iterations, each aimed at improving object detection accuracy, speed, and adaptability to various applications, from surveillance and autonomous driving to forensic evidence analysis in the field of computer vision.

### 2.3 YOLO v8 advantages over previous versions:

Accuracy: YOLOv8 is more accurate than previous versions of YOLO.
Speed: YOLOv8 is faster than previous versions of YOLO, and it is faster even on smaller devices where CPU power is limited.
YOLOv8 is a state-of-the-art object detection algorithm that is more accurate, faster, and more robust than previous versions of YOLO.

## 3. YOLO in Forensic Science

### 3.1 Introduction

Forensic science is multi-disciplinary field that plays most important role in solving crime cases, forensic evidence collection, evidence analysis, documents verification etc. it involves various techniques, principles and methods to collect, investigate, analyze evidence related to criminal cases, documents fraud cases and cybercrime cases. The main objective or task of forensic science is to uncover the truth and provide scientifically valid information to law enforcement agencies, advocates and the criminal justice system. There are various fields in forensic science like forensic chemistry, pathology, anthropology, entomology, odontology, digital forensic. Etc. The field of forensic science is a most important component or field of criminal justice system. It combines forensic expertise with available forensic data like evidence, documents, mobile devices, and hard disk anything that is related to crime case and accurately concludes the information to help justice systems.

### 3.2 Need of Object Detection in forensic science

With increase in crime cases in various fields like insurance documents fraud, cyber-crimes like UPI payment frauds, social media violent posts, ATM hacks, bank robbery etc. the forensic data that needs to be analyzed has increased tremendously and so the number of pending cases. To solve this issue we need automatic real time evidence detection system, who can detect evidence of our interest accurately and precisely. And thus need of real time object detection term came into picture. Computerized automatic object/evidence detection system help forensic expert to quickly find out evidence or detect objects of their interest form CCTV footage, video clips from mobile phones, photos collected from crime scene sites, fake documents submitted to insurance claims or any other legal use. Real time object detection systems performs very tedious and time consuming tasks in very less times where human expertise required more time even in days. There are various object detection algorithms available with having advantages and disadvantages. With real time object detection capabilities and accuracy with speed and can work on low end devices YOLO object detection model is very useful among all other models. In coming sections we will discuss, how we can use YOLO in forensic science evidence analysis.

### 3.3 YOLO in forensic science

YOLOv8 is a deep learning object detection model that can be used for various tasks like detection, segmentation, classification and pose estimation [13]. Each of this task has different objective and use case to perform. Here are the ways YOLO v8 can be applied in the field of Forensic Science:

**3.3.1 Crime Scene Evidence Analysis**: YOLO can be used to detect and locate objects of interest with bounding boxes and detection confidence around it at a crime scene. A system made with YOLO model can easily and quickly identify and classifies objects/evidence such as guns, axe, sword, blood stains, evidence of interest, hammer, shattered glass, or a relevant objects, in images or videos such as CCTV footage, video clips from smartphones or hard disks, pen drives found at crime scene, which can help forensic experts in their analysis and speed up the process of investigation that ultimately leads to quick justice to sufferer.

**3.3.2 Facial Recognition:** YOLO can be used with images and video footage from CCTV or any other source to accurately identify suspects, victims etc. in criminal investigation. This can be helpful in theft tracking using different CCTV footage. In this process face of theft can be detected and tracked along different footages [14].

**3.3.3 Vehicle registration number recognition:** YOLO can be used to detect and identify number plates [17] on vehicles. This is most valuable information for tracking and identifying vehicles involved in crimes. This will give the vehicle owner information like name, address, and contact number if available. Examples of this use case can be hit and run case, kidnapping case, chain snatching with running bike.

**3.3.4 Forensic Evidence Analysis:** YOLO can be used by forensic experts to analyze images and videos for identification of weapons, objects of interest or ballistic evidence which is crucial in solving criminal cases [18].

**3.3.5 Object Tracking:** As YOLO is real time object detection model, its real-time ability can be useful in tracking and monitoring movement of suspect in real time using CCTV cameras. This can be helpful in prevention of crime or predicting crime before happening [14]. This further can help law enforcement agencies to quickly act on it.

**3.3.6 Forensic Imaging:** YOLO can be used for photos and video clips enhancement, enabling detection and extraction of tampered or hidden data or information in multimedia evidence [16].

**3.3.7 Scene Reconstruction:** YOLO can help in re-constructing crime scene by detecting and locating objects/evidences and individual objects in various frames of video footage.

### 3.4 Advantages of YOLO in Forensic Evidence Analysis

**3.4.1 Speed and Efficiency**: YOLO is well known for its real-time processing, which makes it better choice for quickly analyzing large sets of images or video footage from CCTV or any other source. It can detect objects interest very quickly and efficiently.
**3.4.2 Accuracy**: YOLO model has trained on a wide range of datasets and can achieve higher accuracy in object detection. This is important in forensic evidence analysis as evidences are most important.
**3.4.3 Scalability**: YOLO model can be installed on variety of hardware, from low end CPUs to high end GPUs which can be useful in different forensic scenarios like we can deploy this model inside CCTV camera itself to output data of our interest with boxes or labels around it.
**3.4.4 Consistency**: YOLO model ensures a consistent approach to real time object detection and analysis, reducing the chance of human error in the forensic evidence detection.

Here we highlighted some of the main advantages of YOLO model. Other than this using YOLO in forensic evidence analysis has various advantages such as Object tracking, Automation, Evidence preservation etc.

## 4. Technical aspects of YOLO V8

YOLOv8 was launched in 2023 by Ultralytics, the company that developed YOLOv5. YOLOv8 provides five versions: YOLOv8n-nano, YOLOv8s-small, YOLOv8m-medium, YOLOv8l-large and YOLOv8x-extra-large.YOLOv8 supports multiple tasks such as object detection, segmentation, pose estimation, tracking, and classification [15].

**4.1 Architecture of YOLO v8**: The architecture [19] of YOLO v8 is built upon previous versions of YOLO algorithms. YOLOv8 utilizes a convolutional neural network that can be divided into two main parts: the backbone and the head. A modified version of the CSPDarknet53 architecture forms the backbone of YOLOv8. This architecture consists of 53 convolutional layers and employs cross-stage partial connections to improve information flow between the different layers. The head of YOLOv8 consists of multiple convolutional layers followed by a series of fully connected layers. These layers are responsible for predicting bounding boxes, objectness scores, and class probabilities for the objects detected in an image.

One of the key features of YOLOv8 is the use of a self-attention mechanism in the head of the network. This mechanism allows the model to focus on different parts of the image and adjust the importance of different features based on their relevance to the task. Another important feature of YOLOv8 is its ability to perform multi-scaled object detection. The model utilizes a feature pyramid network to detect objects of different sizes and scales within an image. This feature pyramid network consists of multiple layers that detect objects

at different scales, allowing the model to detect large and small objects within an image. It functions by splitting the input image into a grid and forecasting the bounding boxes and class probabilities for each grid cell. YOLO uses a single neural network to predict outcomes and can recognize several items at once with great accuracy.

**4.1 Challenges for configuring YOLO in forensic applications**: The YOLO is a popular object detection algorithm, but using it in the field of forensic science presents some unique challenges

**4.1.1 Limited Data**: Forensic datasets are often smaller and less diverse than generic object detection datasets. YOLO's performance depends on the availability of a substantial amount of labeled data. An insufficient amount of data can lead to poor model performance.

**4.1.2 Fine-Grained Object Detection**: In forensic applications, the objects of interest can be small and intricately detailed, such as fingerprints or tiny pieces of evidence. YOLO might struggle with fine-grained object detection, as it's primarily designed for detecting larger objects.

**4.1.3 Variable Lighting Conditions**: Forensic scenes can have extreme variations in lighting conditions, including low light and reflections. YOLO may require additional pre-processing or fine-tuning to handle these variations effectively.

**4.1.4 Noise and Artifacts**: Forensic images may contain noise, artifacts, or distortions that can confuse object detection models. Pre-processing and data cleaning may be necessary to reduce the impact of such issues.
Here we discussed some of the challenges but there might be other challenges such as chain of custody, privacy concerns, real-time detection, class imbalance, etc.

**5. Future Scope and Research Opportunities**

**5.1 Future Scope:** As we know population and crimes are increasing day by day need of high speed investigation systems are required to fulfill the investigation process. So future of these field is very bright. In coming days forensic expertise with automatic computerized object detection systems are highly required in the justice system to investigate crimes.

**5.2 Research Opportunities:**

The field of forensic science is a multidisciplinary field with more number of subfields. As YOLO object detection algorithms requires dataset which is made using YOLO algorithms or any other algorithms requires huge data i.e. images in thousands with accurately annotated objects, accurately labeled objects. As we increase classes i.e. objects dataset increases because to detect object more precisely we need at least 1000 images per object. That gives good detection efficiency. So created high quality datasets is a big research opportunity in this field. Because in any object detection model dataset quality is always plus point as we are dealing with the field of forensic science, the evidence can be found on grass, or in such a condition where it is hard to predict the class of object. In this situation quality of dataset being used plays crucial role.

Fine-Grained Object Detection
Multi-Modal Data Fusion
Forensic Scene Reconstruction
Forensic Video Analysis
Privacy-Preserving Object Detection
Chain of Custody Tracking
Real-Time Forensic Analysis
Cross-Domain Transfer Learning
Model Explain ability
Ethical and Legal Considerations
Validation and Benchmarking
Collaboration with Forensic Experts
Dataset Creation

All above are good opportunities to explore in the field of forensic science with the use of automatic object detection and real time models like YOLO v8.

## CONCLUSIONS

The rising rate of crimes and the increasing complexity of forensic evidence detection and analysis have prompted the need for advanced technological solutions. Object detection models, particularly the state-of-the-art You Only Look Once (YOLO) series, have emerged as crucial tools in the field of forensic science. YOLO's ability to rapidly and accurately detect objects in real time has transformed forensic evidence analysis, making it more efficient and effective.

However, using YOLO in forensic applications comes with unique challenges, such as limited data, fine-grained object detection, variable lighting conditions, and dealing with noise and artifacts. Overcoming these challenges and addressing issues like chain of custody, privacy concerns, and class imbalance require ongoing research and development.

The future of forensic science and automatic object detection systems is promising, as they are essential for efficient and timely investigations. Research opportunities in this field include creating high-quality datasets, fine-grained object detection, multi-modal data fusion, forensic scene reconstruction, privacy-preserving object detection, chain of custody tracking, real-time forensic analysis, cross-domain transfer learning, model explain ability, ethical and legal considerations, validation and benchmarking, and collaboration with forensic experts.

As technology continues to advance, the integration of YOLO and other object detection models into forensic science promises to play a pivotal role in improving the speed and accuracy of evidence detection and analysis, ultimately contributing to the swift delivery of justice and the resolution of criminal cases.

## ABBREVIATIONS

| | |
|---|---|
| ADAS | Automated Driver Assistance System |
| YOLO | You Look Only Once |
| CNN | Convolutional Neural Networks |
| R-CNN | Regions with Convolutional Neural Networks |
| CCTV | Closed Circuit Tele-Vision |
| FPN | Feature Pyramid Network |
| SOTA | State Of The Art |
| COCO | Common Objects in Context |
| CPU | Central Processing Unit |
| GPU | Graphics Processor Unit |
| AI | Artificial Intelligence |

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