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Artificial Intelligence-Based Techniques for Crime Scene Reconstruction and Investigation: An Overview

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Abstract

Crime Scene Reconstruction (CSR) is a crucial component of criminal investigations and calls for a careful examination of the available data to pinpoint the chain of events that led to the crime. There has been an increase in the demand for using AI-based techniques for crime scene reconstruction since the advent of Artificial Intelligence (AI). We compared the developments, drawbacks, and potential applications of` AI-based crime scene reconstruction systems. We discovered that machine learning models, computer vision models, natural language processing models, deep learning models, and graph analytics models have all demonstrated considerable gains in crime scene reconstruction. However, there are also limitations to the use of AI-based techniques, including the need for large amounts of high-quality data, potential bias in the data or algorithms, and the interpretability of the results. To overcome these limitations, future research should focus on developing more robust and transparent AI-based models that integrate multiple techniques and provide clear explanations of the results. Over the past few decades, 3D modeling has been the subject of extensive research. Overall, AI-based techniques have the potential to revolutionize crime scene reconstruction, but further research is needed to optimize their use in criminal investigations. This comparative review addresses how AI is being used in forensic science now and in the future.

Keywords: Artificial intelligence • 3D modeling • Crime scene reconstruction

Introduction

A nation's economic prosperity depends heavily on safety, security, and an effective justice system [1]. Crime is a broad term that refers to any behaviour or action that violates the law and is punishable by the legal system. Crime scene represents the area where criminal activity takes place as well as the traces and evidence it leaves behind over a specific period of time and location. Crime scene reconstruction is a process of analyzing physical evidence and eyewitness accounts to determine the sequence of events that occurred during a crime. This process is a critical part of criminal investigations, as it helps law enforcement officials identify potential suspects, determine the type of crime that was committed, and build a case that can be used in court. The term "AI" can refer to a variety of concepts, including concrete forms of AI like machine learning as well as hypothetical AI that meets awareness and sensitivity requirements. The field of computer science known as Artificial Intelligence (AI) is primarily concerned with creating intelligent, intuitive technology. In a number of ways, Artificial Intelligence (AI) has the potential to enhance crime detection and investigation. Following are some examples of how AI can be applied to improve crime detection: Police prediction, Facial identification, Processing of natural language, automated analysis of the evidence and reconstructing a crime scene. From an AI forensic perspective, experiments on AI as a tool crime imply that AI systems or services are used to commit physical crimes or assist in cybercrimes [2].

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Artificial Intelligence (AI) has the potential to revolutionize crime scene reconstruction by providing new tools and methods for analyzing and interpreting evidence. AI algorithms can process vast amounts of data and identify patterns that might be missed by human investigators alone. AI can be used to identify important pieces of evidence, reconstruct complex crime scenes, and even predict future criminal behaviour. In order to protect the forensic validity of digital data during investigations, digital forensics and related subfields have continuously developing policies and processes. When developing policies and procedures suitable for failure investigations in AI-enabled systems, AI Forensics seeks to replicate these ideas. The goal of AI model forensics, which is regarded as a subset of the AI forensics issue, is to address and support the forensic soundness of artefacts related to AI models, such as files, logs, authenticity, classification history, etc. These can be used to describe the diversity and connections among the various roles and states of the criminal, the crime scene, and the criminal process. They can also be used to forecast the various types of crime scenes that might appear in different scenarios and to direct or control the evolution of the criminal process in various states through computational experiments. Applications for artificial intelligence include image processing, blood pattern detection and analysis, crime scene reconstruction, digital forensics, and, of course, satellite monitoring. This review comprises of some major AI models that are have been put to use in forensic evidence analysis purposes and in different state of the art CSR techniques. The article also suggests some future perspectives regarding the usage and development of these models on a broad scale in forensic agencies and possibilities of advancements in the models.

Literature Review

AI model classification and their implementation techniques in different fields of forensic

To reconstruct the events that took place during a crime, machine learning models can be trained on a range of data, including physical evidence and witness accounts. These models can be used to find patterns in the data that human investigators might not see right away [3]. Machine learning algorithms, for instance, can be used to analyse a bullet's trajectory to pinpoint the shooter's

location or the distribution of blood spatter to pinpoint the attack angle. To find prospective suspects or re-enact the events of a crime scene, computer vision models can be used to examine video or photographic evidence. These models can be trained to identify particular items, like guns or cars, as well as to follow people as they move around an area. For instance, computer vision models can be used to track a suspect's movements inside a structure or to determine the brand and model of a car that was used in a crime. Text information pertaining to a crime, such as witness accounts, police records, or social media posts, can be analysed using natural language processing models. These models can be used to find important facts or patterns in the data that might aid in reconstructing the actual occurrences. Natural language processing models, for instance, can be used to find recurring themes or expressions in witness testimony that might point to collaboration between several suspects. Crime scenes can be virtually created using 3D modelling techniques so that they can be viewed and examined by AI models [4]. These models can be used to rebuild the events in a more realistic and interactive way, giving investigators a greater understanding of how they happened and a chance to see any gaps in the testimony of witnesses or the reliability of physical evidence.

Discussion

Utilization AI-based automation technologies in forensic & criminal science

Forensic and criminal science is increasingly using AI-based automation tools to increase the precision and effectiveness of their investigations. Crime scene DNA samples can be examined using AI-based automated tools. Large amounts of DNA data can be analysed by machine learning models to find trends and predict the identification of the suspect. This can speed up and improve the accuracy of the investigation's suspect-narrowing process.

Photographs of suspects can be compared using facial recognition software to photographs from social media profiles or surveillance footage. Large image datasets can be used to train machine learning models, which will increase accuracy and decrease false positives. In circumstances where the suspect is unknown to the victim, this technology can aid police in more swiftly identifying suspects. Large amounts of text data, including those found in police reports, witness interviews, and social media posts, can be analysed using AI-based automation systems. Patterns and keywords that may be pertinent to the research can be found using natural language processing models. This can aid detectives in finding prospective leads and better comprehending the circumstances around the incident [5].

Data from crime scenes, such as blood spatter patterns, gunshot trajectories, and footprints, can be analysed using AI-based automation systems. Large databases of crime scene data can be used to train machine learning models to look for patterns and anticipate possible outcomes (Figure 1). This can aid investigators in more precisely reconstructing the timeline of events. Artificial Intelligence (AI)-based automation tools can be used to examine financial transactions and spot any potential fraud-related tendencies. In order to discover anomalous patterns of behaviour or transactions, machine learning models can be trained [6]. This can assist investigators in spotting suspected fraudsters.

Documents and text data from many languages can be translated using AI-based automation technology. This can be especially helpful in circumstances involving foreign investigations or where the suspect is not a native speaker of the investigative language. Digital evidence including email records, social media posts, and chat discussions can be examined using automated methods based on Artificial Intelligence (AI) [7]. While machine learning models can be used to find patterns in network traffic data, natural language processing models can be used to spot possible threats or questionable behaviour. Decisions on sentencing and parole can be made using AI-based automation tools, which can analyse information about a defendant's criminal past and personal traits to provide recommendations. Large databases of previous court data can be used to train machine learning models, which can then be used to find trends and forecast the likelihood of recidivism (Table 1).

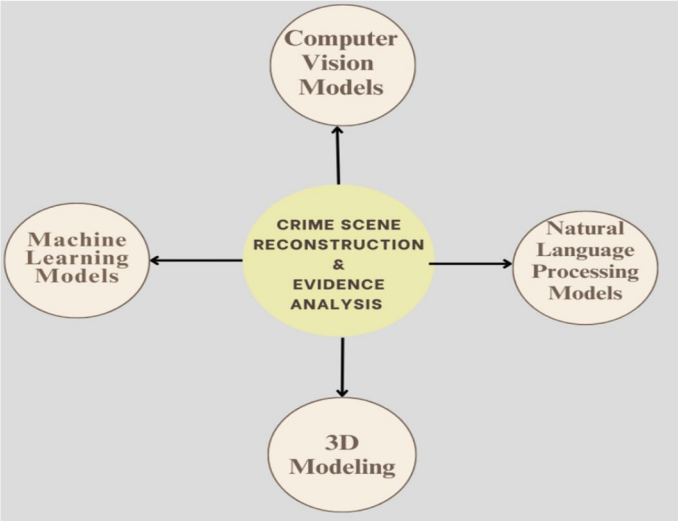

Figure 1. Artificial intelligence based model associated with CSR.

Limitations & Future Advancements

The analysis and interpretation of complicated data from crime scenes is made easier for investigators by the use of Artificial Intelligence (AI) models in crime scene reconstruction. To increase the precision and efficacy of AI models in this area, however, there are still some restrictions and difficulties that must be overcome. The incapacity of existing AI models to contextualise evidence in the same manner that human investigators can is one of their key limitations. AI may not be able to comprehend the subtleties of a specific crime scene, such as the position of evidence, the time of day, or the presence of witnesses, despite its ability to analyse data fast and precisely. Furthermore, AI models could be biassed as a result of the training data they get, which could result in inaccurate conclusions. The requirement for high-quality data poses another difficulty. Large volumes of data are used by AI algorithms to identify trends and make predictions. Data for crime scene reconstruction can be restricted, particularly when there are few witnesses or scant physical evidence. For AI algorithms, this can make it challenging to forecast outcomes accurately.

Future developments might enhance the capacity of AI models for crime scene reconstruction in a number of ways. To gather additional information about crime scenes, one strategy is to merge AI models with other technology, such as sensors and drones. This could assist to get around the drawbacks of only using tangible evidence and eyewitness testimony. The creation of explainable AI models is another exciting field of study. These models' decision-making procedures are intended to be more transparent, enabling researchers to better understand how the model arrived at a certain result. This could lower the chance of bias and improve the precision of forecasts.

One of the major advancements of CSR through AI and deep learning technology could be use of blockchain technology majorly for securing and maintaining the flow of data. Blockchain technology may be used to safely store and distribute evidentiary data amongst investigators, forensic specialists, and other important parties in the context of crime scene reconstruction. This can lessen the chance of data loss or manipulation and assist to maintain the integrity of the evidence. Blockchain technology can also make it easier to follow evidence over the course of an inquiry by establishing a clear chain of custody and enhancing transparency. However, the application of blockchain technology to crime scene reconstruction is still in its infancy, and further study is required to fully explore its applications in this area.

Conclusion

In summary, blockchain technology and AI models have the potential to greatly enhance the precision, effectiveness, and transparency of crime scene reconstruction. Blockchain technology can securely store and distribute

Table 1. Overview of artificial intelligence based techniques and models developed in the past years with their critical analysis.

Model Name/Scanner	Type of Model	Application	Limitations
3D Mapping Technology	3D Modeling	Blood Spatter Analysis, Police Shooting, Surface Deviation Analysis of a blunt object, Accident Cases, Arson Cases	When feasible, all aspects of supposition or depiction of what is uncertain should be avoided. If they must be included, these parts should be made much known.
IC-Crime	3D Modeling	Creates a realistic 3D Model of the crime scene using "Story Editor" and "Cinematic Creator"	Hardware System is not optimal, Laser Scanner is large and process of scanning is time consuming.
Kinect v2 RGB-D sensor	3D Modeling	Crime Scene Documentation, Multi-Modal Dataset of different aspects of crime scene	No further assistance in broad usage as of now in the field.
Unreal Development Kit (UDK)	Computer Vision	Based on Virtual Reality for Crime Scene Simulator	The simulator should be kept always in order to avoid any anomalies during the simulation.
3D Hawk	3D Modeling	Crime Scene Investigation	On Paper Documentation needs to be done manually
FARO X 130 scanner	3D Modeling	3D Mapping of crime scene and mapping accuracy	Documentation of CS is manual
HandySCAN 700 Scanner	3D Modeling	3D Models are based on the sketches provided	Only useful in cases of indoor crime scenes
LiDAR Smart 3D Capture	3D Modeling, Computer Vision	Blood Spatter Trajectory Analysis, CSR	No setup for automatic documentation
GOM ATOS	3D Modeling, Computer Vision	Virtual Crime Scene Digitising in homicide and accidental cases & Documentation is also done digitally	Measurements need to be taken normally and fed into the system for recreation
Instant Scene Modeler	3D Modeling	3D Reconstruction and sensors can also be embedded for visual motion parameters estimation	Manual Documentation and Measurements
LiDAR	Machine Learning, 3D Modeling	Virtual CSR, Documentation done digitally	NA
FLIR Titanium	3D Modeling	3D Imaging with thermal Information as well	Documentation needs to be done manually
(Online Gaming Farming Entwork Analysis (OGFNA)	Machine Learning, Natural Language Processing Models, Computer Vision	Gold Framing Groups Detection, Trading Network Analysis, Detection of anomalies in trade patterns, and thus it can be applied to other game genres with economic functions, including trades between users	NA

evidentiary data amongst necessary parties, while AI models can assist with the analysis and interpretation of complicated data from crime scenes. To assure the efficacy and dependability of these technologies, however, there are still some restrictions and difficulties that need to be resolved. The capabilities of AI models and blockchain technology in crime scene reconstruction must be continually improved in order to realise their full potential. These technologies have the potential to completely transform the discipline of forensic science by increasing the precision and efficiency of investigations and, eventually, raising public safety.

Conflict of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

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