



THE ROLE OF AI IN FORENSIC SCIENCE: THE FUTURE OF CRIMINAL JUSTICE

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ABSTRACT

Artificial Intelligence (AI) is revolutionizing by enhancing precision, efficiency, and speed in criminal investigations. AI technologies, including crime scene reconstruction, DNA analysis, digital forensics, and pattern recognition, are significantly transforming various forensic disciplines. This review explores the application of AI in Forensic Science while addressing associated challenges, ethical dilemmas, and legal considerations with real scenarios. Additionally, the article highlights the future prospects of AI in forensic science, emphasizing its potential integration with other emerging technologies to further advance the field of criminal justice.

INTRODUCTION

Technology has become an indispensable part of modern life, standing alongside fundamental human necessities such as food, clothing, and shelter. At the core of this technological evolution is Artificial Intelligence (AI), which refers to the simulation of human intelligence in machines programmed to think and act like humans. These tasks include problem-solving, understanding language, reasoning and much more.¹ In recent years, AI has proven to be instrumental in enhancing the effectiveness of forensic science, a field crucial for ensuring the conviction of the guilty and the exoneration of the innocent.

AI presents an opportunity to transform the relationship between criminal adjudication and forensic expertise, facilitating a paradigm shift in evidence analysis and presentation. Despite its potential, there remains a lack of comprehensive research and findings on how AI can improve the success and reliability of forensic processes. By simulating human cognitive

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¹ Altayari, W., Kamalrudin and et.al The role of artificial intelligence in forensic evidence presentation.(2022) International Journal of Health Sciences, 6(S2), 5649≤5662. <https://doi.org/10.53730/ijhs.v6nS2.64> accessed on 8th December 2024.

abilities such as visual perception and decision-making, AI-driven innovations have significantly advanced the accuracy and efficiency of criminal investigations. Tools such as 3D scanners and virtual reality technologies further aid in the meticulous identification and analysis of evidence, uncovering critical details that might otherwise go unnoticed.

The purpose of AI is not to replace humans but to support them in forensic analysis. While human expertise remains vital for interpreting and analyzing data, AI provides transparency and aids in reducing biases and wrongful convictions, making the field of forensics more efficient and equitable.

CURRENT APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN FORENSIC SCIENCE

The application of Artificial intelligence in forensic science is generally intertwined, AI has been studied as an assisting tool in forensic pathology that can be applied to solve the problems that experts have been having for decades with the identification of facial and speaker comparison, handwriting and age estimation even from an unknown person's skull bone is done by creating a 3D image by a superimposition technique. Forensic science plays a crucial role in uncovering evidence from crime scenes, helping to clarify the facts and ensure that the guilty are held accountable. However, much of the work is still performed by humans especially trace evidence such as blood & body fluid stains, gunshot residues, weapon marks, etc it takes time to perform operations and also make human errors while doing so, by utilizing the approach of Artificial Intelligence will make things much faster, and smoother compared to the forensic experts². The following have been explained in detail:-

Crime Scene Reconstruction

AI technologies are transforming the methodology of crime scene Investigation. One of the game-changing features of AI in forensic science is object recognition and evidence detection. This system will require inputs such as the presence of objects at the crime scene, for instance, a dead body or other items after thoroughly analyzing each input, it will generate 3 to 4 animated videos independently, which will be of great help to Forensic experts as compared to

² Sahu A, Tripathy P and et.al. AI Applications in Forensic Science: Transforming Crime Scene Analysis and Investigation.accessed on 8th December,2024

now, which involves manual construction of animated crime scenes along with the posture of the victim as well³.

3D scanning, AI and Virtual Reality

Laser scanning is the greatest digital model of the crime scene, it captures millions of data points. AI-powered scanners not only capture but also analyse it in real time detecting things like blood spatter patterns or which the human eye commonly miss those evidences. Once the scene is captured digitally it can be revisited by anyone or either lawyers, jurors and even investigators.

Digital Forensics

Digital forensics is an advanced discipline, the practice of investigating, recording and reporting cybercrimes to prevent future attacks is known as digital or computer forensics. It has further become a rapidly growing field in criminal investigations. The integration of AI is particularly crucial, given the rising prominence of technology in modern crimes.

Digital forensic experts are the detectives of the digital age. However strong the defense systems are but are exposed to cyber attacks in today's world cyber security experts are required to gather and analyze evidence in a court of law, or else attackers retain unfettered access to an organisation's network further damages and possible legal repercussions⁴. The use of artificial and intelligent technologies and techniques can address these issues by offline intrusion analysis and by safeguarding the information infrastructure's integrity and privacy.

Pattern Detention

Pattern Detention is another important aspect of crime investigation. It is a process of automated machine recognition, categorized based on the type of learning procedure involved used to generate the output value. Artificial Intelligence can become more effective in the identification of these trends in complex data. Under this when there are multiple crime scene that seems unrelated, AI detects certain patterns to identify to help reconstruct a more accurate

³ Dror IE, Morgan RM. A futuristic vision of forensic science. *Journal of Forensic Sciences*. 2020;65(1):8-10. accessed on 7th December 2024

⁴ Costantini S, De Gasperis G and et.al. Digital forensics and investigations meet artificial intelligence. *Annals of Mathematics and Artificial Intelligence*. 2019;86(1):193-229. accessed on 7th December 2024

timeline of events, it also improves the law enforcement officers and the de-escalation techniques.

Predictive Policy

Predictive policing is an intervention model to reduce crime and improve public safety. This two-pronged approach combines advanced analytics with intervention models, enabling law enforcement to shift from reacting to crimes to predicting when and where incidents are likely to occur, allowing for strategic resource deployment. It also complements existing strategies such as problem-oriented policing, community policing, intelligence-led policing, and hot spot policing.

In 2015, the Maharashtra Police adopted AI technologies to enhance crime control by implementing predictive policing software. As part of this initiative, the department also acquired Universal Forensic Extraction Devices (UFED) from leading global brands specializing in digital forensics and investigations. These advanced devices can retrieve data, including deleted information, from mobile phones, social networking platforms, hard drives, and other digital devices. Additionally, they are capable of recovering audio-visual data from drones and CCTV cameras, significantly aiding in crime-solving efforts.

Biometric Technology

In criminal investigations, biometric technology development is a current automated approach to identifying an individual associated with physical traits unique physiological and behavioral characteristics to enhance the security and reliability of access control systems. As rise in digital security threats become increasingly sophisticated, biometric technologies, powered by artificial intelligence (AI), offer a robust solution for protecting sensitive information. Common biometric modalities, such as fingerprints, facial recognition, and voiceprints, provide a high level of accuracy and can greatly enhance the security of authentication processes. Each of these identifiers plays a vital role in ensuring reliable and efficient identity verification. One of the most commonly used biometric methods is fingerprint recognition. Modern fingerprint scanners use AI algorithms to analyse ridge patterns, minutiae points, and other unique features of an individual's fingerprints. On the other hand, Facial recognition technology and voice recognition have seen rapid advancements due to AI, it powered facial recognition systems analyze various facial features, such as the distance between the eyes, the shape of the nose, and the contours of the face. Additionally, AI-driven facial recognition can be combined with

liveness detection to prevent spoofing attempts using photographs or masks. Voiceprints are utilized for authentication in telephony and online services. AI enhances voice recognition by distinguishing between various speech patterns and tones, even in noisy environments, ensuring more accurate and reliable verification.

Cyber Forensic

The rise of artificial intelligence (AI) has significantly impacted the domain of cyber crimes due to more sophisticated cyber threats, introducing new capabilities for enhancing security measures and improving investigative processes explores how AI is transforming cyber forensics through advancements in multi-factor authentication(MFA) and adaptive threat mitigation. Integrating AI into cyber forensics enhances individual investigations while bolstering overall cybersecurity frameworks⁵. AI-powered tools enable continuous monitoring and real-time alerts, facilitating proactive threat management and more efficient resource allocation.

AI as a Double-Edged Sword: Legal and Practical Challenges of AI in Forensic Science and How to Overcome Them?

The integration of AI into forensic science introduces a range of legal and practical challenges. While AI enhances efficiency, processes large volumes of data, and aids in decision-making, leading to possible risks. Criminals are increasingly adopting AI tools, as evidenced by the use of deepfake technology to generate pornography as a means of vengeance. These advancements enhance the efficiency of criminal activities, enabling perpetrators to target more victims and make their schemes more convincing. Examining how criminals have historically adapted to new technologies provides valuable insights into how AI might be exploited for illegal purposes in the future.

One significant legal challenge involves the admissibility of AI-generated forensic evidence in courts. Although such evidence is becoming more prevalent, the legal system remains cautious about innovation. A key obstacle is the absence of established protocols to assess the reliability and validity of AI-driven forensic analyses⁶. Traditionally, courts rely on experts to explain

⁵ Hong C, Cho Y. Cyber Threats Analysis of AI Voice Recognition-based Services with Automatic Speaker Verification. *Journal of Internet Computing and Services*. 2021;22(6):33-40. accessed on 10th December 2024

⁶ Thakkar P, Patel D, Hirpara I, Jagani J, Patel S, Shah M, et al. A comprehensive review on computer vision and fuzzy logic in forensic science application. *Annals of Data Science*. 2023;10(3):761-85.accessed on 9th December 2024

how forensic evidence is gathered and analyzed. However, AI algorithms are often too complex to be easily explained in straightforward terms. This complexity has raised concerns about the credibility of AI-derived conclusions in legal proceedings, as poorly understood evidence may undermine its reliability in court.

AI's growing role in forensic science also offers transformative opportunities. Predictive analytics powered by AI can identify potential crime locations based on historical data, enabling law enforcement to allocate resources more effectively and prevent crimes. Additionally, AI-driven virtual reality technology is revolutionizing courtrooms by allowing jurors to interact with crime scenes through digital recreations, offering a new way to interpret evidence and enhance the pursuit of justice.

The landmark case of *K.S. Puttaswamy v. Union of India* (2017)⁷ underscores the constitutional significance of balancing technological advancements with the right to privacy guaranteed under Article 21. These technological tools, including facial recognition, biometric, and digital data extraction, rely on sensitive personal information, raising concerns about potential misuse and accountability. The judgment highlights the principle of proportionality, requiring that the use of such technologies in criminal investigations be regulated to prevent infringement on individual rights. It serves as a precedent emphasizing the need for a robust legal and ethical framework to ensure technological advancement enhances the criminal justice system without compromising privacy or fairness.

Beyond these advancements, AI models promise to address current limitations in forensic science. For instance, AI can minimize errors in electropherogram readings and improve PCR techniques. It can also aid in age estimation from biological samples left at crime scenes, providing critical insights when traditional DNA matching methods fall short. While these developments highlight the potential of AI to reshape forensic science, addressing the associated legal and practical challenges remains imperative to ensure its effective and ethical application.

REAL SCENARIO

The Delhi Police utilized AI and advanced forensic technologies to investigate 755 cases related to the North East Delhi violence in 2020. About 945 CCTV footage and video recordings

⁷ *K.S. Puttaswamy v. Union of India* (2017) 10 SCC 1

from smartphones were analyzed by using facial recognition and other AI technologies and culprits were arrested. In another incident one person named Solanki, 26 yrs., was shot dead on 24th Feb'2021 behind Rajdhani School, Delhi. The suspect's mobile phone was seized and examined, with the crime being established through the analysis of Google Maps on the device. By the end of 2020, the Delhi Police had solved over 400 cases and filed 342 charge sheets.⁸

Los Angeles, where law enforcement agencies employed advanced tools to assist in a complex active shooter case. In this scenario, AI-powered 3D scanning, combined with machine learning, was used to analyze a vast amount of data collected from point clouds generated by scanning the crime scene. By reconstructing the scene digitally, AI algorithms were able to pinpoint the exact origin of the shots fired, which was crucial in determining the number of shooters involved.

The AI system flagged key data points and conducted trajectory analysis, allowing investigators to accurately simulate the events and narrow down the list of potential suspects. This method greatly enhanced the accuracy and efficiency of the investigation, demonstrating how emerging technologies like AI and 3D scanning are transforming forensic science and improving the ability to solve complex criminal cases.

CONCLUSION

As the future of criminal justice becomes more reliant on AI, the field of forensic science is revolutionizing crime scene investigations, making law enforcement faster and more accurate. While maintaining the dependability of forensic investigation, AI can analyze massive datasets and perform intricate analyses that assist in cross-checking human errors. Recently, researchers have developed AI capable of analyzing a decomposing body to estimate the time of death with unprecedented precision. By studying decomposition processes and environmental factors, AI can assist forensic investigators by offering accurate timelines in cases where determining the time of death is challenging.⁹ This advancement could revolutionize forensic science in criminal investigations. One of AI's advantages is that, as the technology develops, it should become more integrated with cutting-edge technologies like blockchain and virtual reality,

⁸ Sharma S. This AI tool will help Maharashtra Police predict crime. [Internet] Updated 2018 Aug 27[Cited 2022 Apr 26]. <https://www.techcircle.in/2018/08/27/this-ai-tool-will-help-maharashtra-police-predict-crime>. accessed on 6th December 2024

⁹ Zhao H, Li H. Handwriting identification and verification using artificial intelligence-assisted textural features. *Scientific Reports*. 2023;13(1):21739.accessed on 10th December 2024

leading to extremely proactive and transparent forensic procedures. Thus to ensure AI is utilized appropriately in forensic science, however, ethical and legal issues, such as algorithmic bias and doubts regarding the admissibility of AI-generated evidence, must still be resolved to maintain the integrity of justice.