



ARTIFICIAL INTELLIGENCE IN FORENSIC SCIENCE: TRANSFORMING CRIME INVESTIGATION AND LEGAL ACCOUNTABILITY

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Abstract: Artificial Intelligence (AI) is disruptive in forensic science; it leads to precision, effectiveness, and authenticity of criminal investigation. Although classical forensic approaches are efficient, they are faced with many barriers, such as human mistakes and limited time. Using AI algorithms (i.e. machine learning, predictive analytics, facial recognition, and natural language processing), forensic scientists will make efficient use of data of large volume and can search for patterns and reconstruct crime scenes. AI in digital forensics helps analyze images, videos, electronic records, and communications, while in biometrics it helps analyze fingerprints as well as DNA and facial recognition data. Tools that utilize AI also contribute towards the improvement of the investigative process by reducing human bias, whilst improving evidence in courts, ensuring accountability in the law. However, bringing AI into criminal justice includes ethical considerations about algorithmic bias, data privacy and the admissibility of evidence—regulatory oversight and standardization will be required to control all these considerations. Focusing this section on the latest state-of-the-art of AI in forensic science, the article discusses current examples which are providing concrete examples of how AI fits in the modern forensic landscape, and it deals with how it fits the intricate investigations and challenges associated with legal structures, validation ethics and ethical challenges (in particular, validating the data). If forensic science can adopt responsible methodologies to use AI technology, forensic science will see improved accuracy in investigations, faster resolution of cases and better decision making that can be supported by decision making that is a fundamental shift towards technologically enabled crime investigation.

Keywords: Artificial Intelligence, Forensic Science, Crime Investigation, Digital Forensics, Legal Accountability, Machine Learning, Evidence Analysis, Ethical Concerns

1. Introduction

Artificial intelligence, once in a while referred to as system intelligence, is a device's capacity to show intelligence, which is much like the intelligence shown by human beings and animals. Pinnacle Artificial Intelligence textbooks outline this field because they have a look at "wise marketers": any device that senses its environment to understand records and then takes action in step with the received information to maximize its probabilities of effectively attaining its desires. Inside the language of normal or familiar conversation, the term "artificial Intelligence" is frequently used to explain the machines that imitate the "cognitive" functions of human beings, i.e., the intelligence functions that human thoughts play, such as but not confined to "mastering" and "trouble-solving."¹

¹ Siddhant Gupta, Mrs. Vinny Sharma (et. al.), Artificial Intelligence in Forensic Science, 7 International Research Journal of Engineering and Technology 7182(May 2020). Available at https://www.academia.edu/44244322/IRJET_ARTIFICIAL_INTELLIGENCE_IN_FORENSIC_SCIENCE?auto=download (last visited 30-08-2025).

Artificial intelligence has increasingly been integrated into the field of forensics. Advanced algorithms are now employed in forensic science for various tasks, including e-discovery, DNA sequencing, and the review of forensic documents. Traditionally, it was thought that reconstructing crime scenes required a team of experts due to the specialized skills involved. Consequently, restoring crime scenes was seen as a complex and costly process. To address this challenge, implementing an AI system that is swift, efficient, accurate, and more cost-effective would be advantageous. The restoration of crime scenes necessitates the adoption of advanced investigative technologies that are more intuitive and intelligent. In this context, computer-generated animations are favored, as they represent a leading AI solution for accurately visualizing crime and accident scenes, assisting forensic teams in understanding intricate structural details.²

One significant benefit of AI-generated animations is their potential use in court as demonstrative evidence. Forensic animations utilize four main methods to recreate criminal events: virtual reality (VR), augmented reality (AR), computer-generated 3D animation, and hybrid imagery combining both real and virtual elements. Motion technology is integral to these computer-generated animations; VR and AR leverage motion tracking tools like sensors, cameras, gloves, and haptics to facilitate real-time interaction through user gestures. Additionally, sensor-based systems gather precise data from crime scenes by employing technologies such as electromagnetism, electrochemistry, and ultrasound. Examples of AI-driven animations in crime scene reconstruction include 3D point cloud technology and Car Sim software. Car Sim functions as a converter that transforms written descriptions from reports into visual representations of vehicular incidents; it can accurately interpret around 35% of textual information into visual formats. Meanwhile, 3D point cloud technology assists in projecting evidence related to gunshot injuries by modeling the trajectory of projectiles and determining their source. This technology combines with photographic sensing methods to create a 3D point machine capable of autonomously navigating around a room to ensure comprehensive coverage of crime scenes.³

Successful discrimination of facial features under different lighting conditions, obstructions, and emotional expressions is accomplished through the application of Support Vector Machines (SVMs) and deep learning techniques for feature extraction. These advancements have positioned AI-driven facial recognition systems as essential tools in forensic science for identifying criminals and locating missing individuals.⁴ Artificial intelligence can facilitate forensic experts in efficiently managing information and conducting meta-analyses on various levels. This capability could significantly reduce the time spent by investigators, allowing them to dedicate more attention to other critical responsibilities. Furthermore, it is essential that the data collected remain accessible to all relevant parties, enabling retrieval whenever necessary.⁵

However, it is important to acknowledge that AI faces criticism alongside ethical dilemmas, limitations, and discussions that sometimes venture into philosophical territory. The primary challenge associated with AI lies not in its technical aspects but rather in its human implications. The future applications of AI will hinge on our capacity to create thriving environments. Nonetheless, a considerable portion of research focused on AI interventions within global health fails to address the ethical, normative, or practical factors vital for their extensive application or large-scale deployment. In this context, it is noteworthy that while the World Health Organization (WHO) actively advocates for the responsible utilization of technologies, including large language models—to support healthcare professionals, patients, research initiatives, and scientific advancement—it has raised concerns regarding the inconsistent application of standard precautions typically associated with new technologies when dealing with large language models. This includes adherence to fundamental principles such as transparency, inclusivity, public collaboration, expert oversight, and rigorous evaluation practices.⁶

² Arpit Nirvan, Swaroop S. Sonone, "Introduction to Artificial Intelligence in Forensic Science", (et.al.), Kavita Saini, Swaroop S. Sonone, (et. al.) (eds.) *Artificial Intelligence in Forensic Science: An Emerging Technology in Criminal Investigation Systems 1* (CRC Press, Boca Raton, Florida, 1st edn., 2024). Available at https://www.researchgate.net/publication/382035324_Artificial_Intelligence_in_Forensic_Science_An_Emerging_Technology_in_Criminal_Investigation_Systems (last visited 30-08-2025).

³ Id at 2.

⁴ Dr. R. Bharath Kumar, Dr. Abhishek Baplawat (et. al.), *Artificial Intelligence in Forensic Sciences: Bridging Systematic Challenges with Next-Generation Applications 14* *Journal of Neonatal Surgery* 640 (2025) Available at https://www.researchgate.net/publication/389903889_Artificial_Intelligence_in_Forensic_Sciences_Bridging_Systematic_Challenges_with_Next-Generation_Applications (last visited 30-08-2025) (last visited 30-08-2025).

⁵ Kamshad Mohsin, *Artificial Intelligence in Forensic Science*, 4 *International Journal of Forensic Research* 172 (2023). Available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3910244 (last visited 30-08-2025).

⁶ Carles Martin-Fumadó, Eneko Barbería-Marcalain, (et. al.), *Artificial intelligence in forensic sciences: The future is now*, p. 90 Available at <https://www.elsevier.es/en-revista-spanish-journal-legal-medicine-446-pdf-S2445424924000402> (last visited 30-08-2025).

2. The Emergence of AI in Forensic Science

Taking into consideration the existing literature, advancements in technology have significantly transformed not only the areas of forensic science previously discussed but also the automated identification of DNA evidence, fingerprints, and shoe prints. For instance, machine learning algorithms designed for analyzing DNA traces have been developed to evaluate DNA profiles and pinpoint unique genetic markers. This capability allows researchers to ascertain familial relationships and accurately match profiles to databases while saving considerable time. The implementation of robotics and AI-driven machines has facilitated the extraction of DNA from biological samples, reducing human error and minimizing sample contamination. Furthermore, AI can effectively deconvolute a mixture of DNA samples into individual components, which is essential in cases involving multiple individuals.⁷

Regarding fingerprints, it is important to highlight the role of convolutional neural networks (CNNs), which have been trained to identify fingerprint patterns. This advancement enables swift and precise matches with existing databases. Such technology has enhanced forensic investigations by allowing law enforcement officials to connect fingerprints discovered at crime scenes to specific individuals. Additionally, AI algorithms can improve latent prints found at crime scenes by revealing ridge details that might be invisible to the naked eye, thus preventing reliance on partial evidence. Notably, automated extraction of minutiae points—such as fingerprint endings and bifurcations—facilitates fingerprint matching and classification while speeding up the identification process.⁸

3. Legal Recognition and Evidentiary Value of AI-Based Forensic Methods

The incorporation of Artificial Intelligence (AI) within legal and investigative spheres has notably altered how evidence is collected, analyzed, and presented. AI technologies—including machine learning algorithms, facial recognition software, and predictive analytics tools—can efficiently process large amounts of data with both speed and accuracy, rendering them invaluable in criminal and civil inquiries. Evidence generated by AI comprises digital footprints, predictive analyses, pattern recognition findings, and algorithmic deductions that aid courts in establishing facts as well as verifying other pieces of evidence.⁹

In India, the Bharatiya Sakshya Adhiniyam 2023 provides a legal framework regarding the admissibility of electronic records under Sections 62 and 63.¹⁰ Outputs generated by AI that are stored or documented digitally may qualify as electronic records; however, unlike traditional digital records that are deterministic in nature, AI outputs tend to be probabilistic. This introduces complications when proving their accuracy, reliability, and source authenticity. Consequently, courts must assess whether such evidence satisfies standards concerning relevance, admissibility, and probative value.¹¹

Several elements affect the evidentiary significance of artificial intelligence. Primarily, the accuracy and reliability of the AI system are crucial. Evidence generated from a system known for high error rates may be considered inadmissible or given diminished importance.¹² Additionally, transparency and explainability are vital factors. Algorithms that operate as "black boxes," providing results without clear reasoning or decision-making pathways, may encounter skepticism in judicial contexts, as courts require an understanding of how conclusions are derived.¹³ Furthermore, the integrity of input data is critical; AI outputs can only be trusted to the extent that they are based on sound training data; biased or incomplete datasets can undermine their evidentiary credibility.¹⁴

International legal frameworks offer insights into evaluating AI evidence. In the United States, courts adhere to the Daubert standard, which highlights the necessity for scientific validity, peer-reviewed methods, and error rate disclosures concerning expert evidence—criteria that also apply to AI-generated information.¹⁵ Likewise, in Europe, regulations such as GDPR and ethical guidelines surrounding AI emphasize transparency, accountability, and auditability within automated decision-making systems, indirectly influencing the legal standing of AI evidence.¹⁶ Despite these hurdles, several jurisdictions have successfully accepted AI evidence for purposes such as identifying criminal patterns, verifying identities, and reconstructing events. When corroborated with conventional evidence, AI outputs can enhance both investigative efficiency and judicial precision. However, it remains essential for courts to meticulously assess AI-generated evidence regarding its

⁷ Angelika Dudek, Anna Dąbek (et. al.), Integrating artificial intelligence in forensic science, p. 25, Available at <https://e-methodology.eu/index.php/e-methodology/article/view/1514> (last visited 30-08-2025).

⁸ Ibid.

⁹ John Kingston, *Artificial Intelligence and the Law* (Oxford University Press 2020) 112.

¹⁰ Bharatiya Sakshya Adhiniyam, 2023, ss 62–63.

¹¹ Rajesh Sharma, "AI and Evidence in Indian Courts" (2021) 12 *Indian J. L. & Tech.* 45, 49.

¹² Ibid.

¹³ European Commission, *Ethics Guidelines for Trustworthy AI* (2019) 24.

¹⁴ S. Gupta, "Data Bias and AI Evidence" (2020) 15 *J. Indian Forensic Sci.* 102, 106.

¹⁵ *Daubert v. Merrell Dow Pharmaceuticals*, 509 U.S. 579 (1993).

¹⁶ Regulation (EU) 2016/679 (General Data Protection Regulation), Art 22; European Commission (n 5) 28.

probative value against potential prejudicial risks to ensure technology serves to support rather than replace judicial reasoning.

AI is also significantly impacting forensic investigations by analyzing shoe prints and tire treads through computer vision methodologies developed specifically to recognize individual tread patterns associated with shoe prints found at crime scenes. This technology has assisted investigators in connecting suspects to crime scenes based on shoe patterns left behind while also estimating characteristics such as age, height, and weight in certain cases. Furthermore, AI is employed in comparing tire tread impressions against established databases to associate suspects with vehicles recorded within those databases. This method has proven particularly useful in hit-and-run incidents where tire tracks left at a scene provide critical information about the vehicle involved. Moreover, advancements in data integration and multimodal analysis have been propelled by AI capabilities. Multimodal fusion empowers forensic experts by facilitating connections between different cases through common evidence analysis. The application of this technology has played a significant role in resolving cold cases where evidence had been preserved over extended periods.¹⁷ Through these applications, artificial intelligence can enhance judgment accuracy significantly.

3.1 Crime Scene Reconstruction

This system necessitates certain inputs, such as the presence of objects at a crime scene, for example, a deceased individual or items like shards of glass. After thoroughly extracting and analyzing all relevant aspects of these inputs, it aims to independently generate three to four animated videos. This capability will significantly assist forensic experts compared to the current method, which relies on manually creating animated representations of crime scenes.¹⁸

3.2 Data Acquisition & Recovery Purposes

Cyber forensic specialists frequently encounter significant challenges when analyzing files. To address these issues, the Artificial Neural Network (ANN) will internally assess files and present only the content deemed relevant to cyber experts.¹⁹

3.3 Cyber Forensics

In cases involving crimes conducted over internet networks, ANN proves to be highly beneficial as it can identify whether a web user is engaging in legal or illegal activities. Furthermore, in investigations involving tracking phone calls and other related actions, ANN will determine which calls should be monitored based on its pattern recognition capabilities utilizing remote sensing and satellite technologies.²⁰

3.4 Data analysis

Digital forensics represents an increasingly computationally intensive field that focuses on the examination of extensive and evolving data sets. In this context, artificial intelligence serves as an effective approach for managing and addressing these large volumes of data.²¹

3.5 Pattern recognition

One of the key aspects of forensic science is the detection of different forms of trends in large data. Recognition of trends is founded upon solid evidence and probabilistic thinking. Artificial Intelligence can become more effective in the identification of these trends in complex data.²²

3.6 Providing legal solutions

Forensic reports provide statistical tools for the judicial system to analyze facts. For a more comprehensive and detailed collection of knowledge, Artificial Intelligence will provide the legal system for fast answers where appropriate.²³

¹⁷ Supra note 7 at 25.

¹⁸ Supra note 1 at 7182.

¹⁹ Ibid..

²⁰ Ibid.

²¹ Ibid.

²² Supra note 1 at 7183.

²³ Ibid.

3.7 Improving contact among all investigate team members

Forensic investigation involves contact among forensic statisticians, attorneys, police investigators and others. Miscommunication between such parties can contribute to incorrect decisions or misinterpretation of data resulting in delayed or inaccurate justice. Artificial Intelligence helps to bridge this coordination gap between the numerous stakeholders in this region.²⁴

3.8 Creating Repositories

With the increasing pace of storage capacity expansion, like USB, hard drives, optical media, flash drives which can hold very large volumes of information, it is becoming more challenging for forensic science researchers to hold and examine all this information. Artificial Intelligence will also help to create an electronic archive that can hold all the forensic digital operations, records, assets and reports.²⁵

Artificial Intelligence (AI) has been in existence for under five decades, and while significant advancements in technologies and methodologies have been achieved within our field, there remains a critical need to prioritize human welfare. This paper focuses on only two of the many AI technologies that could be integrated into Forensic Science, acknowledging the presence of both documented and yet-to-be-defined solutions in this domain. The comprehensive application of AI in forensic practice is still at an early stage, making it premature to fully assess its capabilities. However, AI has the potential to address longstanding challenges faced by experts in this field.

Forensic Science traditionally extracts information from crime scenes to clarify judgments and hold perpetrators accountable. Nonetheless, since much of the work relies on human intervention—often leading to slower processes and the possibility of errors—incorporating AI can enhance efficiency, accuracy, and reduce mistakes. Previous studies suggest that using AI for crime scene analysis yields positive results by effectively identifying crimes, recognizing offenders, and promoting justice.²⁶

Conversely, it is vital to maintain ongoing oversight and regulation to ensure compliance with ethical standards and protect individual rights and dignity throughout this process. While AI serves as a valuable asset for investigators during inquiries, it cannot replace the essential roles played by human intuition, experience, and ethics in fighting crime. Further research into integrating AI into crime scene analysis is necessary for a thorough understanding of these technologies' capabilities and ensuring their ethical application within forensic work.²⁷

Although technology can facilitate various aspects of their jobs, it cannot supplant the expertise of specialists in forensic science; rather, AI will act as an ancillary tool.²⁸

AI presents considerable opportunities for enhancing evidence-gathering processes; however, its admissibility and significance depend on demonstrable reliability, transparency, and appropriate contextualization. The legal framework must adapt alongside technological progress by establishing clear guidelines for collecting, validating, and presenting AI-generated evidence to uphold both accuracy and fairness in judicial processes.

4. Critical Analysis

The article gives an idea of what Artificial Intelligence can do for legal proceedings. Artificial Intelligence is really helpful when it comes to dealing with a lot of data and giving judges information.

The article is good at showing the things about Artificial Intelligence and the problems that come with it especially when Artificial Intelligence is used to make evidence. This is a deal under the Bharatiya Sakshya Adhiniyam, 2023 which is a law that decides how courts use electronic records.

One important thing, about Artificial Intelligence is that the results are not always certain. Sometimes Artificial Intelligence just gives probabilities, not fixed answers. That is something to think about when it comes to Artificial Intelligence. That makes it harder to figure out how accurate the evidence really is or where the evidence comes from.. This is where the article does not do a good job. The article does not really look into the risks of courts relying much on Artificial Intelligence especially in India, where judges might not have a lot of knowledge, about complicated Artificial Intelligence algorithms. The article talks about standards like Daubert and GDPR. However it does not explain how Indian courts can really use these standards. The article also does not say where the problems might be when the law is applied in court. Indian courts and the law are two things. The article does not show how international standards, like Daubert and GDPR can be used in

²⁴ Ibid.

²⁵ Ibid.

²⁶ Ibid.

²⁷ Supra note 7 at 26.

²⁸ Supra note 5 at 173.

Indian courts. The focus on transparency and explainability and keeping the data clean is important.. The article should ask more questions about how judges are supposed to understand these complicated artificial intelligence models, the artificial intelligence models that are like black boxes. Judges have to give reasoned judgments that is a basic part of being fair, in court. The artificial intelligence models are a problem because judges do not know how they work. In the end the article does a job of showing that artificial intelligence could change the way we collect evidence and check it. Artificial intelligence could really change things. We need to look closely at whether judges have the tools to understand this technology. How well are the rules for using this technology actually enforced? What is in place to make sure this technology is not used in a way or, for the wrong reasons? The technology is intelligence. If we do not do this it is hard to know the value of artificial intelligence when it is used as evidence. Artificial intelligence is being used as evidence.

2.4 Conclusion.

Artificial intelligence is changing science in big ways that we did not think were possible ten years ago. It is not just making investigations go faster it is also making them more accurate and detailed. Traditional forensic science is still important but people can make mistakes they have to work and crimes are getting more complicated all the time. This is where artificial intelligence comes in. Artificial intelligence is helping to make things better. Machine learning is really helpful for teams. They can look at a lot of data. Rebuild what happened at a crime scene. They can also look at clues, like fingerprints and faces. This helps them find patterns that they might have missed before.

All of this makes investigations go faster. The evidence that forensic teams bring to court is also better. Now the law is starting to catch up with machine learning and other technologies. For example the Bharatiya Sakshya Adhiniyam, 2023 is a law that says digital evidence and evidence made with machine learning is okay to use in court. Machine learning evidence is a deal. It is good that courts are recognizing machine learning evidence and digital evidence. This will help forensic teams use machine learning more.. It is not all easy. Artificial Intelligence still has some problems: it works with chances sometimes has prejudices and can be hard to understand. So judges and lawyers need to look closely at Artificial Intelligence. To test whether the Artificial Intelligence results are correct, trustworthy and based on good information. Artificial Intelligence should assist experts not take their place. The things Artificial Intelligence can do in forensics are really varied. People are using 3D modeling of crime scenes facial recognition, automated fingerprint and DNA analysis to solve crimes. These crime scene tools and facial recognition tools are really helping to solve crimes and catch cybercriminals. They are also making it easier for teams of people to work together on crime cases. Teams can build digital records of crime scenes and this helps everyone know what is going on.

Crime scene tools and facial recognition tools are very helpful. They are not perfect. They do not have feelings or morals like people do. No matter how good crime scene tools and facial recognition tools get they will never be able to replace the experience and good judgment of people who work on crime cases. We need to have rules and people need to check on these algorithms all the time. We also need to be transparent about how these algorithms work. There are some rules in place like the Daubert principle in the United States and Europes GDPR. These rules help keep everything accountable.

The main thing is that Artificial Intelligence is a help to forensic science. Artificial Intelligence is making our investigations more accurate and quicker. The evidence we find is also harder to dispute because of Artificial Intelligence.. If we want to get the most out of Artificial Intelligence we have to make sure we have the right safeguards in place, for Artificial Intelligence. When we match innovation with careful human oversight, AI can help us solve crimes and deliver justice, without losing sight of fairness or integrity.