



Original Article

ARTIFICIAL INTELLIGENCE TRANSFORMING THE FORENSIC SCIENCE

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Abstract:

Artificial Intelligence (AI) is rapidly transforming various scientific fields, including forensic science. Forensic science plays a crucial role in criminal investigations by analyzing physical and digital evidence. The integration of AI technologies such as machine learning, facial recognition, and pattern analysis has improved the accuracy, speed, and efficiency of forensic investigations. AI assists in fingerprint identification, DNA profiling, crime scene reconstruction, and digital forensics. This review paper discusses the role of artificial intelligence in transforming forensic science, its applications, advantages, limitations, ethical concerns, and future prospects. The study highlights how AI enhances decision-making in forensic investigations while also emphasizing the need for responsible and ethical use.

Keywords: *Artificial Intelligence, Forensic Science, Machine Learning, Crime Investigation, Digital Forensics, DNA Analysis*

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Introduction:

Forensic science is a scientific discipline that applies principles of biology, chemistry, physics, and technology to investigate crimes. Traditional forensic methods often require significant time and human expertise. With the advancement of technology, Artificial Intelligence has emerged as a powerful tool in forensic investigations.

Artificial Intelligence refers to the ability of machines to enhance human intelligence such as learning, and problem-solving. AI technologies are now being widely used in forensic science to analyze large datasets, recognize patterns, and provide accurate results. This paper focuses on how AI is transforming forensic science and improving the effectiveness of criminal investigations.



Objectives of the Study:

- The main objectives of this research paper are :
- To study the concept of Artificial Intelligence
- To understand the role of AI in forensic science
- To explore various applications of AI in forensic investigations
- To discuss real issues or cases related to AI usage
- To analyze the future scope of AI in forensic science

Overview of Artificial Intelligence:

Artificial Intelligence is a branch of computer science that focuses on machines to perform tasks that normally require human intelligence. AI systems use algorithms, machine learning, and deep learning to analyze data and make decisions. AI can process large amounts of information quickly and accurately, making it useful in scientific and investigative fields.

Overview of Forensic Science:

Forensic science involves the application of scientific methods to collect, analyze, and interpret evidence related to criminal cases. It includes areas such as fingerprint analysis, DNA profiling, toxicology, ballistics, and digital forensics. Accurate forensic analysis helps law enforcement agencies solve crimes and deliver justice.



Applications of Artificial Intelligence in Forensic Science :

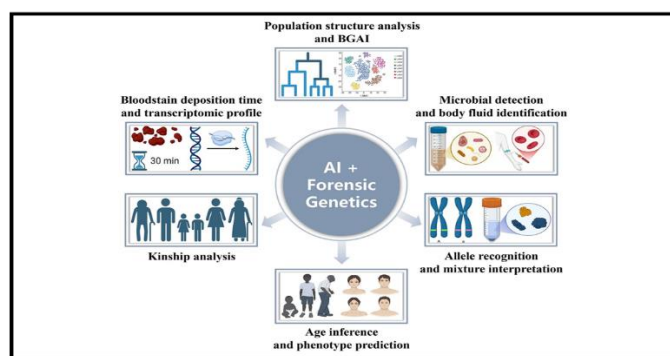
- **Fingerprint Analysis:** AI systems can compare fingerprints with large databases and identify matches with high accuracy. Fingerprint identification is one of the oldest forensic techniques.

Flowchart showing: fingerprint scanning → AI pattern analysis → database matching → identification.

- **DNA Analysis:** Machine learning algorithms help in faster DNA profiling and interpretation of complex genetic data.
- **Facial Recognition:** AI-based facial recognition software is used to identify suspects from CCTV footage. AI helps reconstruct crime scenes by analyzing images, videos, and physical evidence.

Diagram showing: facial image input → AI facial feature extraction → database comparison → suspect identification.

- **Digital Forensics:** AI assists in analyzing digital evidence such as mobile data, emails, and cybercrime records.



Advantages of Artificial Intelligence in Forensic Science:

- Faster processing of forensic evidence
- Improved accuracy and reliability
- Reduction in human errors
- Efficient handling of large databases
- Automation of repetitive tasks



- Support for decision-making
- Increased accuracy and reliability

AI Used as real Forensic Investigation case:

1. AI-Assisted Crime Scene Reconstruction Mumbai Firing Case (January 2026):

In Mumbai, police used advanced AI tools to reconstruct a firing incident and trace bullet trajectories where no clear CCTV or witness evidence existed. AI-enabled forensic analysis helped estimate firing positions and link the incident to a suspect's residence, leading to an arrest and ongoing legal proceedings. This reflects how AI can augment ballistic and crime-scene interpretation in complex cases.

Key points:

- Reconstructed firing paths digitally using AI models.
- Supported forensic specialists in evidence interpretation.
- Showcased practical AI use in non-digital domain (ballistics & reconstruction).

2. MARVEL — Maharashtra's AI-Powered Forensic & Law Enforcement System:

The Maharashtra Advanced Research and Vigilance for Enhanced Law Enforcement (MARVEL) is an AI initiative introduced in 2024 to bring predictive analytics and intelligence support into policing and forensic investigations.

Case highlights:

Hit-and-run suspect tracked hundreds of kilometres: In 2025, MARVEL helped Nagpur rural police locate and apprehend a hit-and-run driver 700 km away, underscoring AI's potential in suspect tracking and cross-jurisdiction profiling.

Predictive patterns: MARVEL analyses data patterns from crime reports, CCTV, and digital footprints to aid investigatory leads.

Integration: Designed to support forensic units by recognizing patterns faster than manual review.

3. AI-Based Biometric Forensics — CID Pilot Project (2025):

The Maharashtra CID piloted an AI-based biometric data collection system in Pune rural police headquarters, automating multi-angle photography, fingerprinting, iris scans and integrating data into the national Crime and Criminal Tracking Network System. AI enables enhanced matching — even if suspects attempt to alter their appearance — facilitating faster identity verification.

Impact:

Automates suspect identification.

Improves forensic biometric records quality.

Aids long-term criminal tracking across multiple regions.

4. Deepfake Detection — 'Vastav.AI' (2025)

Vastav.AI is a deepfake detection system developed in India to detect manipulated photos, videos, and audio using machine learning models. This tool supports digital forensic investigations, especially when digital evidence is contested or suspect to alteration.

Why it matters:

Digital evidence integrity is critical in court.

Deepfake detection becomes a key forensic tool against AI-driven misinformation and fabricated multimedia.

Adopted by police and cybersecurity practitioners in pilot settings.

5. Academic & Training Initiatives Supporting Forensic AI (2024–2025)

Training Programs & Conferences

AI in Forensic Odontology & Medicine Program (April 2025): Interdisciplinary training integrating AI with forensic identification techniques like age



estimation and dental profiling — indicative of capacity building.

Shimla One-Day AI Forensics Workshop (March 2025): Forensic professionals received hands-on learning about AI applications in facial recognition, digital forensics, fingerprint analysis, DNA matching, and speech analysis.

International Conference on AI for Forensics & Biometrics (Dec 2025, IIT Bhilai): A platform for showcasing research and applications at the AI-forensics interface.

Academic Research (2024–2025)

Several Indian forensic science research initiatives explore AI's transformative influence, such as pattern recognition, forensic evidence automation, and predictive modeling in forensic investigations.

These studies contribute frameworks and early evaluations of AI modalities in forensic analyses — crucial for real-world adoption and legal admissibility.

6. Legal & Ethical Considerations in AI Forensics (2025):

Researchers highlight challenges and frameworks for integrating AI tools responsibly in forensic and judicial contexts (e.g., algorithmic bias, explainability, admissibility of AI-derived evidence). Recognizing these issues contributes to shaping protocols and standards in India as AI use expands.

Future Scope of AI in Forensic Science:

AI is set to transform forensic science by making investigations faster, more accurate, and less prone to human error. Future applications include advanced DNA analysis, crime scene reconstruction, predictive policing, and digital forensics, though challenges around ethics, privacy, and legal admissibility remain.

I. Human Identification:

- Facial recognition & biometrics: AI will enhance accuracy in identifying suspects from CCTV footage or social media.
- DNA profiling: Machine learning can speed up matching DNA samples with databases, even in degraded samples.
- Voice & gait recognition: Emerging AI models can identify individuals based on speech patterns or walking styles.

II. Crime Scene Analysis:

- Automated reconstruction: AI can simulate crime scenes in 3D, helping investigators visualize events.
- Pattern recognition: Algorithms detect hidden correlations in evidence (blood spatter, fingerprints, ballistic trajectories).

III. Digital Forensics:

- Cybercrime detection: AI tools can trace hacking attempts, analyze malware, and recover deleted files.
- Social media evidence mining: Natural language processing (NLP) can flag suspicious communications or threats.

IV. Forensic Pathology:

- Postmortem interval estimation: AI models predict time of death more precisely using biological data.
- Cause of death determination: Automated image analysis of autopsies and scans can assist pathologists.

V. Predictive & Preventive Forensics:

- Predictive policing: AI can forecast crime hotspots by analyzing historical data.
- Behavioral profiling: Machine learning may help identify potential offenders before crimes occur (though ethically controversial)



Advantages of AI in Forensic Science:

- **Speed & Efficiency** AI can process DNA samples, fingerprints, and digital evidence much faster than manual methods.
- **Improved Accuracy** Machine learning reduces human error in facial recognition, ballistic analysis, and crime scene reconstruction.
- **Digital Forensics** Power AI tools detect cybercrime patterns, recover deleted files, and analyze large volumes of online communication.
- **Crime Scene Reconstruction** AI-driven 3D modeling helps investigators visualize events and timelines more precisely.
- **Predictive Policing** Algorithms can identify crime hotspots and trends, allowing proactive resource allocation.
- **Consistency & Objectivity**

Limitations and Ethical Issues:

- Despite its advantages, AI has certain limitations:
- High cost of implementation
- Dependence on quality of data
- Risk of biased algorithms
- Data privacy and security concerns
- Ethical issues related to surveillance

Ethical guidelines and regulations are necessary to ensure responsible use of AI in forensic investigations.

Suggestions:

- Automated Evidence Analysis:** Use AI-powered image recognition to analyze fingerprints, footprints, and tool marks faster than manual methods. Deploy deep learning models to detect subtle patterns in DNA sequences or blood spatter analysis.
- Digital Forensics Enhancement:** Apply machine learning to sift through massive amounts of digital evidence (emails, logs, social media) to detect anomalies. AI can reconstruct cybercrime timelines by correlating digital footprints across multiple devices.
- Facial Recognition & Biometrics:** Improve accuracy of facial recognition in surveillance footage using advanced neural networks. Combine multimodal biometrics (face, voice, gait, iris) for stronger identification in criminal investigations.
- Crime Scene Reconstruction:** Use AI-driven 3D modeling and virtual reality to recreate crime scenes for investigators and courtroom presentations. Predict possible sequences of events based on spatial and temporal data.
- Predictive Policing & Crime Pattern Analysis:** AI can analyze historical crime data to predict hotspots and patterns. Helps law enforcement allocate resources more effectively while reducing human bias.



Findings:

AI Application Area	Description / Use Case	Benefits	Challenges / Considerations
Crime Scene Investigation & Reconstruction	AI-powered analysis of crime scene data including photos, videos, sensor inputs; 3D virtual reconstruction of crime scenes for court visualization	Enhances accuracy, identifies overlooked evidence, facilitates virtual courtroom presentations	High data requirements; ethical concerns; reliance on human verification
Digital Forensics & Cybercrime	AI-based pattern recognition, malware detection, social media and network monitoring, automated extraction of hidden or deleted files, blockchain-based evidence custody	Processes large datasets quickly, preserves digital evidence integrity, detects cyber threats	Data privacy issues; algorithmic bias; explainability (black-box AI); cybersecurity threats
Forensic DNA Analysis	Probabilistic genotyping, next-generation sequencing (NGS) data interpretation, complex mixture resolution	Faster and more reliable DNA profiling, improved accuracy for degraded/multi-contributor samples, assists in cold cases	Requires extensive, high-quality datasets; algorithmic transparency; ethical implications
Forensic Toxicology & Drug Analysis	AI detects novel psychoactive substances, analyzes interactions of drugs and poisons in biological samples	Improves drug identification speed, predicts polydrug interactions, aids toxicological interpretation	Limited datasets for rare substances, validation challenges, expert oversight needed
Ballistics & Toolmark Identification	AI algorithms compare firearm marks and bullet casings to databases for weapon identification	Reduces manual workload, increases matching speed and accuracy	Standardization of databases, technical limitations, expert validation
Ethical, Legal, & Operational Considerations	Transparency, algorithmic fairness, data privacy, explainable AI (XAI), human oversight	Builds trust, ensures admissible evidence, equitable for forensic outcomes	Black-box models, regulatory lag, bias mitigation challenges

Conclusion:

Artificial Intelligence has significantly transformed forensic science by enhancing the accuracy, speed, and efficiency of criminal investigations. AI applications such as fingerprint analysis, DNA profiling, facial recognition, and digital forensics have strengthened forensic practices. Although there are limitations and ethical concerns, the benefits of AI outweigh the challenges. With proper regulation and responsible use, artificial intelligence has the potential to revolutionize forensic science and strengthen the criminal justice system. Despite certain limitations and ethical concerns, AI has a promising future in forensic science. Proper implementation and ethical

use of AI can significantly strengthen the criminal justice system.

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