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# Revolutionizing Forensic Science: The Role of Artificial Intelligence in Evidence Analysis

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## Abstract

Artificial intelligence (AI) has had a profound impact on modern society, changing daily life, culture, and industry in previously unheard-of ways. AI has the revolutionary potential to improve evidence processing in forensic science in a variety of domains, including digital forensics, DNA

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

profiling, and gunshot detection. Through the use of sophisticated algorithms, artificial intelligence (AI) simplifies anomaly detection, data processing, and pattern identification, allowing forensic specialists to handle large datasets more quickly and with less human error. With an emphasis on developments in DNA analysis, fingerprint identification, and gunshot detection, this study examines the use of AI in forensic investigations. By resolving the shortcomings of conventional techniques and reducing subjective biases, artificial intelligence (AI) enhances the skills of forensic experts rather than replacing them. These developments mark the beginning of a revolutionary period in forensic science, when technical accuracy supports the administration of justice and public safety.

**Keywords:** *Artificial intelligence, DNA analysis, Genetics, DNA profiling, Forensic DNA analysis, criminal investigation, gunshot and AI, gunshot detection, object detection*

## Introduction

The idea of building robots is frequently cited as the origin of artificial intelligence (AI). The word “robot”, which comes from the Czech word “robota”, was first used by author Karel Capek in his play “R.U.R” (Rossum’s Universal Robots) in 1921. McCarthy (1955), father of Artificial Intelligence, defined it as “the science and engineering of making intelligent machines”. AI is the ability of machines to perceive and respond to its environment independently and perform tasks. However, no human intervention is involved. According to NV, K and E. (2022) the review paper delves into AI which refers to “computer intelligence that is employed to reduce the burden of human beings”. AI has evolved dramatically over the last few decades and the implications of the AI revolution are already being felt in many sectors of society. However, the unique characteristics of AI and the methods by which AI can be generated have social, ethical, policy

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

and legal ramifications. The rise in AI raised concerns about the accountability for crime committed by AI. As there are no policy guidelines in India, which eventually attract legal and ethical issues about its application. This analysis aims to define AI for legal purposes and to analyze whom to hold liable when crime is committed by AI entities

Artificial intelligence is a system that demonstrates intelligent behavior by assessing their surroundings and acting, somewhat independently to accomplish objectives. One could consider artificial to be a product created by people, frequently as a replica of something which naturally exists whereas intelligence includes the capacity to learn and comprehend with challenging situations. AI can carry out nearly all a person's intellectual tasks and can do as well as experience emotions such as joy, sorrow, rage, or even love and regulate them through independent human like actions. Artificial intelligence plays a pivotal role in contemporary society, significantly contributing to innovations across various fields, including crime.

AI has revolutionary possibilities in forensic sciences. Enhancing accuracy, efficiency, and investigative capacities is the promise of integrating AI technologies in the industry. AI can analyze complicated forensic data, including digital evidence and DNA profiles, with remarkable speed and accuracy thanks to sophisticated algorithms and machine learning. By cutting down on the amount of time required for evidence analysis and improving the precision of autopsies and crime scene reconstructions, this skill greatly benefits forensic specialists. AI will help forensic professionals in India by enabling better diagnostic tools, predictive analytics to spot crime trends, and sophisticated data management systems that facilitate quicker case resolutions. AI is therefore poised to transform forensic science in India by offering strong instruments that improve the precision and effectiveness of forensic practice, ultimately leading to more effective justice delivery and public service.

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

The purpose of the present review paper is to explore the transformative role of artificial intelligence (AI) in forensic science, particularly in evidence analysis. By examining key areas such as DNA profiling, fingerprint recognition, and gunshot detection, the paper highlights how AI enhances the accuracy, efficiency, and reliability of forensic investigations. It aims to address the limitations of traditional methods, reduce human error, and provide insights into the ethical and legal implications of AI in forensic applications. This review underscores the potential of AI as a collaborative tool for forensic professionals, advancing justice and improving public safety.

***Artificial Intelligence and DNA analysis***

According to Sessa et al., (2024), the term artificial intelligence (AI) has effectively permeated various medical specialties. AI and forensic sciences are two fields that are increasingly overlapping and have enormous potential for resolving intricate criminal investigations. Two areas have received the most attention when it comes to the use of AI in forensic genetics. For instance, several studies have looked into how AI can be used to improve and speed up the classification of DNA samples, additionally, to reduce the possibility of misunderstanding.

According to Vilhekar and Rawekar (2024) a review was conducted on artificial intelligence in DNA analysis in which the researchers delved into the current uses of AI in genetics and DNA Analysis. The authors suggested that AI is a powerful tool for creating new hypotheses and helping with experimental techniques. AI can be helpful in detecting heredity and gene related disorders.

According to Wang (2023) a study was conducted on DNA analysis in forensics into which the researcher found that one of the biggest advances in forensic science has been the 1953 discovery of DNA structure by Francis Crick and James Watson, as well as the development of DNA sampling, profiling, and analysis. Because an individual’s DNA is distinct it leaves behind

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

permanent traces of who we are, which greatly aids forensic scientists and law enforcement in identifying both criminals and victims. The study of physical, biochemical, and behavioral characteristics is known as genetics, or it is the study of DNA and how it is passed down through generations.

***DNA Extraction Techniques in Forensic***

Modern forensic science now relies heavily on forensic DNA analysis, which has transformed criminal investigations and the administration of justice. Law enforcement organizations now have an unmatched advantage thanks to the capacity to extract and examine DNA from a variety of biological samples, including blood, hair, skin cells, and saliva Instrument to identify victims, connect people to crime scenes, and clear innocent people. Because DNA evidence can identify people with high specificity and accuracy, it is frequently regarded as the gold standard in court. Promising answers to these problems can be found in emerging forensic DNA analysis technologies like rapid DNA analysis, next-generation sequencing (NGS), and artificial intelligence (AI). These developments expand the uses of DNA analysis and speed up its accuracy, allowing forensic scientists to work with more deteriorated samples and retrieve valuable data from intricate DNA blends.

| EMERGING TECHNOLOGIES | DESCRIPTION | BENEFITS | APPLICATIONS |
|---|---|---|---|
| **1 .3D Genomics and Spatial DNA Analysis** | Technology that provides spatial context for understanding DNA | Provides spatial context for DNA evidence | Crime scene reconstruction, complex DNA |

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

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|---|---|---|---|
| | evidence at crime scenes. | | mixtures |
| **2. AI and Machine Learning** | Software-driven analysis of large forensic data sets to find patterns and make prediction | Improves efficiency in data analysis and interpretation | Large-scale forensic investigations |
| **3. Next Generation Sequencing (NGS)** | High-throughput technology that sequences multiple DNA fragments simultaneously | Higher resolution, better insights into complex samples | Cold cases, complex mixture analysis |
| **4. Mobile DNA analysis** | Field-deployable DNA analysis platforms for remote or field based forensic investigations. | Provides DNA analysis onsite in remote locations or during field operations | Disaster recovery, battlefield, remote crime scenes |
| **5. Rapid DNA Analysis** | Portable technology designed to generate DNA profiles in under 2 hours at point of-need | Fast results, ideal for time sensitive cases | Border checkpoints, disaster recovery |

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

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|---|---|---|---|
| **6. Automated Extraction Systems** | Fully automated systems that handle the entire DNA extraction process | Increases throughput, reduces human error, improves consistency | High-volume forensic labs |

**Table 1**. *This table provides an overview of key emerging DNA technologies, outlining their main benefits, challenges, practical considerations for their application, current level of adoption, and common forensic scenarios where each technology is most applicable. It serves as a reference tool for forensic professionals looking to navigate the selection of advanced DNA technologies for specific cases (Source, Alketbi 2024)*

Mullis (1983) created the polymerase chain reaction (PCR) method, which became a significant milestone in DNA testing and earned him a Nobel Prize in science in 1993. PCR enabled the swift replication of specific nucleotide sequences in DNA in a laboratory setting. The resulting amplified products are known as amplicons. PCR is sometimes known as “Molecular Xeroxing.” The PCR assay has multiple benefits over the RFLP approach. One benefit is that PCR has greater sensitivity, requiring less starting material. With PCR, a DNA profile can be generated from a sample that is 100 times smaller than what is needed for RFLP. Additionally, PCR can analyze a DNA molecule that has been degraded (broken into smaller fragments) for typing purposes. This is particularly significant since much of the DNA collected at crime scenes tends to be degraded. Due to these advantages, the PCR method is currently the primary technique used for DNA profiling. The use of PCR in forensic science originally relied on amplified fragment length polymorphisms (AFLPs). The AFLP system's PCR method focused on the specific locus D1S80. The D1S80 analysis technique proved valuable as it allowed for the examination of small and degraded samples.

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

Although PCR of AFLPs was successful, DNA profilers transitioned to PCR of short tandem repeats (STRs) in the 1990s; this method utilizes much smaller repeat units, typically ranging from 2 to 7 bp in length. STRs are also known as microsatellites or simple sequence repeats. The brief length of the repeat unit makes it easier to amplify, and they are less vulnerable to issues related to degrade DNA. Additionally, smaller amounts of DNA are needed for PCR of STRs. This enables the analysis of small, partially degraded DNA samples. Another benefit is that PCR of STRs facilitates multiplexing, which allows for the simultaneous analysis of several different loci. After establishing a DNA profile from an unknown sample, one can statistically estimate the probability that a specific individual possesses a certain allele at a designated locus.

In conclusion, the use of artificial intelligence to DNA analysis represents a major advancement in forensic science by providing increased scalability, speed, and precision. DNA profiling has been transformed by AI-driven methods like machine learning and pattern recognition, which automate intricate procedures, enhance the interpretation of deteriorated samples, and allow for quick identification in urgent situations. AI improves forensic accuracy, lowers human error, and expedites investigation workflows by overcoming conventional constraints. Additionally, its capacity to examine big genetic databases offers insightful information about inherited characteristics and gene-related illnesses, opening the door for developments outside of forensics, such as genetic and medical research. AI promises to improve DNA analysis even more as it develops, guaranteeing more trustworthy results and solidifying its place as a fundamental component of contemporary forensic investigations.

***Artificial Intelligence and Fingerprints***

For more than a century, fingerprint analysis has been a fundamental component of forensic science, progressing from simple ink and paper methods to complex digital imaging and pattern

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

recognition techniques. This type of biometrics has had a major influence on the criminal justice system throughout its history by being essential to criminal investigations, evidence gathering, and the identifying process.

In forensic investigations, fingerprint analysis has shown to be an essential technique for identifying people and connecting them to crimes. Our methods of analyzing fingerprints are changing as technology develops. We examine how fingerprint analysis has changed over time, from conventional techniques to the way artificial intelligence is transforming the industry.

In the past, fingerprint analysis was primarily conducted using ink and paper methods where fingerprints were manually recorded and compared to identify individuals. However, traditional methods of fingerprint analysis faced several limitations, including lower accuracy rates and higher error rates due to the manual nature of the analysis. Such limitations not only hindered the efficiency of forensic investigations but also raised concerns about the reliability of evidence presented in court. The demand for more advanced technologies to enhance the speed and precision of fingerprint analysis grew as a response to these persistent issues. Whereas important technical advancement is the use of AI in fingerprint analysis, which uses sophisticated automation and machine learning algorithms to improve the precision and effectiveness of forensic investigations.

To process and analyze enormous datasets and enable sophisticated pattern recognition and data interpretation, artificial intelligence in fingerprint analysis uses machine learning methods.

To identify distinctive patterns and traits, these machine learning algorithms are trained on enormous volumes of fingerprint data. AI systems can recognize patterns and irregularities in fingerprints using data processing techniques, which help forensic investigators solve challenging cases. With predictive modelling, improved decision-making skills, and cutting-edge technology, artificial intelligence in forensic is set to transform the discipline and bring about major

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

improvements in both criminal justice and forensic investigations. AI will become more and more important as it will automate processes, increase accuracy, and give forensic professionals strong tools to solve challenging cases. We also look at how AI increased forensic investigation accuracy and casts doubt on the notion that fingerprints are unique. Come along as we explore how AI might change forensics in future.

In conclusion, fingerprint analysis has been transformed by artificial intelligence, moving from manual techniques to sophisticated automated systems. AI greatly improves fingerprint identification's precision, effectiveness, and dependability by utilizing machine learning algorithms and advanced data processing techniques. It reduces human error in forensic investigations, enhances the clarity of latent prints, and makes it possible to quickly identify distinctive patterns. AI also makes it easier to manage massive fingerprint databases, which speeds up criminal identification and case resolution. As AI technology develops, its incorporation into fingerprint analysis will further expedite forensic procedures, bolster the validity of evidence, and support the overarching objective of effectively and efficiently administering justice.

***Artificial Intelligence and Gunshot Detection***

The identification of irregular, unexpected, unpredictable, and unusual events or items that are not regarded as regularly occurring events or items in a pattern or objects included in a dataset and are hence distinct from preexisting patterns is known as weapon or anomaly detection. A pattern that deviates from a collection of typical patterns is called an anomaly. As a result, anomalies rely on the relevant phenomenon. Feature extraction and learning techniques or models are used in object identification to identify occurrences of different item categories. Accurate gun detection and classification is the main goal of proposed implementation. Accuracy is also very important as false alarm could result in an unfavorable reaction. Making the appropriate approach

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

between speed and accuracy requires selecting the right strategy that illustrates the deep learning-based weapons identification algorithm. The input video's frames are taken out. Before an object is detected, the frame differencing algorithm is used, and a bounding box is constructed.

Security is always a major concern as crime rate rises in crowded places or suspicious lonely areas due to growing demand in the protection of safety, security and personal properties with computer vision applications addressing abnormal detection and monitoring video surveillance systems are needed. Weapon detection is the identification of irregular, unexpected, and unusual events or items in a dataset that different from existing patterns, indicating a lack of regularity in the dataset. Weapon detection using artificial intelligence (AI) involves the use of advanced algorithms and computer vision techniques to identify and classify weapons in various settings. This technology is often employed in security systems to enhance safety and prevent potential threats. Violence committed with guns puts a significant impact on public, health, psychological, and economic costs. Many people die each year from gun-related violence. Psychological trauma is frequent among children who are exposed to high levels of violence in their communities or through the media.

According to Singh et al., (2024) artificial intelligence refers to a task performed or controlled by computers to make it easy and require less or no manpower. Fingerprints are now being used as a major tool in the identification of human beings. Fingerprints are also evidence of major importance, which helps in criminal investigations. The Fingerprint recognition system or fingerprint biometry is an excellent tool that identifies fingerprints with the help of an artificial intelligence. The traditional fingerprint development methods require power, and the developed prints might not always be very clear or identifiable whereas as biometric devices, the fingerprint gets recognized quickly with the help of computer software. such artificial intelligence, space

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

software has several advantages over traditional methods like speed, ease of use, accuracy and storage. Hence the system is widely being preferred over conventional techniques.

According to Matrooshi (2024) this review paper aimed to identify the motives and justification for the use of artificial intelligence in predicting crime to explain the challenges of artificial intelligence algorithm, the risk of bias and their ethical rules and to highlight the role of artificial intelligence in identifying the criminal fingerprints during the detection of crime. The research relied on an analytical approach, for the purpose of identifying the motives and justification for the use of intelligence. The results of the research revealed the effectiveness of artificial intelligence techniques, the result and their positive impact in the field of criminal investigation and identifying the criminal fingerprints. Artificial intelligence provides great scientific solutions that contribute to raising the value of labor tree results and understanding and analysing forensic evidence.

According to Qianqian Pan and Jun Wu (2024) with the development of artificial intelligence and electronic technologies. Large AI models are promoted to process complex tasks due to resource limitation and devices are powerless in training complex large AI models which intend to adopt AI model service provided by resource sufficient cloud servers named machine learning as a service (MLAAS) . However, in MLAAS, there exists a critical smart data leakage issue that is the abuse of AI models without permission. To solve the above issues, they proposed a physically unclonable function (PUF), empowered AI hardware fingerprint approach to protect AI model intellectual property. First a PUF empowered AI model D protection framework is processed including device specific AI hardware, fingerprint empowered authentication and MLAAS subscription. Second, we propose an AI hardware, fingerprint, enable and device authentication protocol to support device and key storage less authentication third based on the

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

device by AI hardware, fingerprint the paper device, MLAAS subscriptions and providing scheme is designed. Experimental results verify the reliability and effectiveness of the proposed PUF based AI hardware fingerprint approach.

According to Cheng and Schmidt (2024) a review was conducted on AI in gunshot wounds to classify entry and exit of gunshot wounds of how it damages or hurt the body. Dl which is a type of AI has proven to be capable and even surpasses human performance. DL has been widely used for histopathological cancer identification/grading. One of the earliest uses of artificial intelligence in forensic pathology is this study. This study shows that a DL model can be trained to reasonably accurately distinguish entrance and exit GSWs in digital images. In difficult scenarios where AI cannot accurately categorize a GSW, further details such as the case's circumstances, radiography, and the capacity to control the body itself are necessary to produce a more definitive evaluation.

According to Lawrence, Vigne and Thompson (2019), Goff detection technology (GDT), a device that automatically detects gunfire and instantly notifies law enforcement officials via a network of outdoor sound sensors. The Urban Institute evaluated GDT in three cities with funding from the National Institute of Justice to record how agencies use and execute the technology and determine its effects on shootings alerts, reaction times, incidence of violent crimes, and interactions between the police and the community. The cities that took part in this study were Richmond, California; Milwaukee, Wisconsin; and Denver, Colorado. All three cities employ ShotSpotter, Inc.'s GDT device, even though it is produced and sold by several vendors**.**

According to Raponi, Oligeri and Ali (2022), the difficult task of classifying a weapon based on its muzzle blast has important applications in several military and security domains. To accurately detect and identify the acoustic source, the majority of current works rely on the ad hoc

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

deployment of spatially diverse microphone sensors to capture multiple replicas of the same gunshot. However, in situations like crime scene forensic, it is challenging to carefully control setups rendering the previously mentioned techniques unusable and unfeasible presented that is entirely independent of the relative positions of the microphone and shooter and necessitates no prior knowledge of the recording setup. Using a dataset of 3655 samples taken from YouTube videos, our solution achieves over 90% accuracy in ident. A new method is identifying the gunshot model, caliber, and category. Our findings show how Convolutional Neural Networks (CNNs) can be used effectively and efficiently for gunshot classification, removing the need for an ad hoc setup while greatly enhancing classification performance.

## Conclusion

A future where the search for truth is balanced with technological accuracy is promised by the revolutionary crescendo that is the fusion of artificial intelligence and forensic science. The field of artificial intelligence has made remarkable progress in the past five years and is having real world impact on people, institutions and culture. Ai systems often rely on personal data. Ai plays a pivotal role in enhancing the quality and efficiency of evidence collection, preservation and presentation in digital era. It focuses mainly on extracting electronic data that can be used as evidence in an investigation. AI can significantly accelerate DNA Analysis, predict DNA profiles and assist in complex kinship analysis. Ai can also help in improving the accuracy an speed of fingerprint analysis in various ways such as automating fingerprint matching, enhancing latent prints and identifying unique features. Ai can reduce the risk of human error and speeding up the investigation. The use of AI in crime scene analysis, as demonstrated via automated evidence gathering and processing, highlights how it has the potential to completely transform the effectiveness and precision of investigations.

Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

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Vol. 3, Issue 1 January 2025 ISSN: 2584-0142

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