INFORMATION & TECHNOLOGY

# Forensic Science and Role of AI in It

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**Received:** 21 August 2026 **Published:** 23 October 2026 **Volume 13, Issue 4** (Oct–Dec 2026)
**Article no.:** e206 **Open access** · free to read

Forensic Science is the application of the methods of the natural and physical sciences to matters of criminal and civil law. Forensic science is a set of scientific methods and expertise used to investigate crimes or examine evidence that might be presented in a court of law.

Forensic science comprises a diverse array of disciplines, from fingerprint and DNA analysis to the analysis of synthetic opioids and digital evidence.

Forensic science plays a crucial role in our criminal justice system. Forensic science can be involved not only in investigation and prosecution of crimes but also in matters in which a crime has not been committed but in which someone is charged with a civil wrong or causing industrial injuries. Forensic science can help investigators collect, rapidly analyse, and interpret complex evidence to solve crimes, including cases that have long been unsolved. It can help exclude innocent people from an investigation or exonerate them in cases of wrongful conviction. It can also help juries as they make decisions that have enormous consequences on the lives of alleged perpetrators.

Criminalistics and forensic science are both branches of forensic science that involve the application of scientific principles and techniques to solve crimes. However, criminalistics focuses more on the analysis of physical evidence such as fingerprints, DNA, and ballistics, while forensic science encompasses a broader range of disciplines including toxicology, anthropology, and entomology. Both fields play a crucial role in the criminal justice system by providing valuable evidence that can help investigators identify suspects, link crimes, and ultimately bring perpetrators to justice.

### *Branches of Forensic Science*

• **Forensic Anthropology:**

It is a field of physical anthropology that deals with skeletal remains, skeletonized bodies, and bones. Sometimes, the crimes are so brutal that it becomes quite difficult to identify the victims and here forensic anthropology comes into the picture. Forensic Scientists help to investigate the crime by using scientific techniques. They examine the dead remains of humans and animals and thus give an estimated time of death.

When the body of the deceased becomes unrecognizable due to mutilations, burning, or natural degradation, forensic anthropology helps in their identification by face reconstruction. These experts determine the age, sex, occupation, height, and cause of death i.e. murder, accident, or suicide. Interestingly, they can also determine whether the injury on the body was caused before the death or during the death.

• **Forensic Engineering:**

It helps in the investigation of a case where the machines are involved. The experts examine and identify the machinery failure that caused deaths or physical injuries. It involves the examination of the mechanical and structural failures and thus helps in the identification of the responsible entity for the losses that occurred.

• **Forensic Odontology:**

Odontologists use dental records in identification of the dead or missing people. They study the bite marks, dental impressions, and dental X-rays and present them as legal evidence in court. Teeth are hard structures and

hence can tolerate huge physical impacts thus they are preserved and used for identification. In case of a plane crash when the entire body is damaged the arrangement of teeth being a unique feature helps in the identification.

• **Forensic Pathology:**

As the name suggests when science is collaborated with path labs it is called forensic pathology. It helps in the determination of the cause of death by examining the corpse.

These people can identify the weapon used in the murder. They study the medical history of the victims and, when needed perform autopsies as well and examine the evidence collected from the crime site.

• **Forensic Entomology:**

It involves the use of insects and arthropods in solving criminal cases. Students learn the interaction mechanism of arthropods with a dead body. Through insects, they determine whether there was any involvement of drugs or any kind of poison in the crime.

• **Toxicology**:

Under this, the students learn how toxic chemicals affect humans, animals, and the surrounding environment. They examine the involvement of any kind of poisonous substance involved in the crime mystery. Sometimes it becomes quite difficult to conclude whether the death is caused by overdose or it is a planned murder. In such cases, toxicology helps in analysing the cause of death by examining blood, urine, food, and beverages that the deceased had before his demise.

• **Forensic DNA Fingerprinting:**

It is one of the most important branches of forensic science. It involves studying the biological evidence involved in cases. For example, cases that involve unanimity of identity, testing the parentage, identifying the dead or missing, sexual assault, decomposed body, and skeletal remains are solved using the DNA Fingerprinting method. As no two people can share the same set of fingerprints they are the most reliable evidence and thus are used in the investigation and identifying the culprit.

• **DNA Analysis:**

Apart from fingerprints, DNA profiling is another forensic technique that is used in criminal investigations. The evidences that are used in DNA analysis are hair, skin, semen, urine, blood, and saliva. In cases where the body is found burnt and it is not possible to get the skin, blood, or saliva sample in such cases the body remains can also be used.

• **Forensic Archeology:**

In cases where the victim’s body or his belongings or stolen goods or evidence are buried, forensic archeologists help the police in the investigation. They use archeological techniques along with photography and imaging techniques. These people also carry out excavations at historical sites to produce the war crimes trial evidence and similar other cases.

• **Digital Forensics:**

With the growth of digitalization, crimes are also traced to digital or electronic forms. Digital forensics majorly deals with cyber-crimes such as phishing, malware attacks, pornography, and stalking. It helps in the examination of the digital evidence that includes computers, mobile phones, hard disks, USB drives, and other electronic devices. Digital forensics majorly deals with cyber-crimes and digital evidence that need to be presented in a court of law.

• **Questioned Document:**

This branch of forensics deals with suspicious documents involved in both civil and criminal cases. The suspicious documents include forged signatures on documents or cheques, counterfeit currency, suicide letters, anonymous letters associated with the cases, forged passports, damaged documents, printed or xeroxed documents, etc. Apart from these documents, the examination of handwriting analysis is also done under this branch.

• **Forensic Ballistic:**

This branch deals with the analysis of evidence related to arms and ammunition like pistols, bullets, revolvers, rifles, primers, pellets, propellants, fired bullets and cartridge cases, residues of the gunshot, and marks on ammunition such as pin marks. The experts conclude which weapon was used in the crime, its distance from the incident site, velocity, and angle of firing, and ultimately reveals the identity of the shooter as well.

• **Forensic Psychology**:

When science is linked with psychology in solving criminal and civil cases, it becomes Forensic Psychology. Experts assist the police in criminal profiling by studying crimes and criminals. They carry out interrogation and counselling of people involved in crime and thus make inferences about the personality traits of the criminals. Various psychological and psychometric tests like Polygraph tests, Narcotic Analysis, Brain mapping, etc are done under forensic psychologists.

• **Forensic Podiatry:**

This branch of forensics deals with the abnormalities and diseases of the lower body particularly the ankle and foot, lower limb, and musculoskeletal system. In many cases, the criminals act so smart that they try to erase evidence from the scene, and to some extent, they succeed in it also. In these situations, the experts dig out the foot-based evidence and use it in solving the cases.

• **Forensic Linguistics:**

Forensic Linguistic experts analyse the written and spoken language of the people involved in crime and thus conclude the age, sex, educational qualification, culture, ethnicity, socio-economic background, and spiritual and religious beliefs. They are considered experts for cases involving emergency calls, demands of ransom, suicide notes, social media posts, and death row statements.

• **Forensic Geology:**

Forensic Geologists examine the evidence related to the earth’s materials for example oil, petroleum, minerals, natural gases, soil, rocks, etc. The experts analyse these substances recovered from the suspect, victim, or crime site and thus answer the questions raised by the legal system.

There are also other branches of forensic science such as forensic biology, physics and chemistry, forensic accounting, etc.

### *Contribution of AI in Forensic Science*

Human identification is critical in forensic cases, especially when physical identification is impossible due to decomposition or trauma. Traditionally, methods like fingerprint analysis, DNA profiling, and dental records were used. Now, AI-based tools like DENT-net, a CNN (Convolutional Neural Network), have been introduced to streamline this process.

Traditionally, Postmortem Interval (PMI) estimation is based on temperature changes, rigor mortis, or decomposition stages. However, these methods are highly variable, depending on environmental conditions. AI techniques like Fourier Transform Infrared (FTIR) spectroscopy have been developed to analyse changes in biological tissues after death, providing a more accurate estimate of PMI. Garland et al., similarly employed AI to process gross images of visceral organs, achieving over 95% accuracy in PMI estimation. This automated process allows forensic pathologists to determine time of death more efficiently, improving the accuracy of

crime scene investigations. The determination of the Cause of Death (COD) is crucial in any forensic investigation, but it can often be complicated by complex injuries or environmental factors. AI systems, particularly CNNs and BPNNs (Backpropagation Neural Networks), are being developed to assist in this challenging task.

For example, DeepIR, a CNN-based model, is used to analyse pulmonary edema fluid samples to predict causes of death such as drowning, asphyxiation, and sudden cardiac arrest. AI technologies in forensic science include Convolutional Neural Networks (CNNs), Artificial Neural Networks (ANNs), Backpropagation Neural Networks (BPNNs), k-Nearest Neighbor (k- NN) Algorithm and Robust Object Detection Framework (RODF).

The AI revolution has brought many changes in the different fields of medicine, including forensic pathology. Different fields of this medical specialty could be assisted by AI and specifically ML algorithms. FA, forensic dentistry, estimation of PMI, and COD are some of

these fields. While challenges remain, such as the need for larger datasets and improved hardware, the future of forensic sciences is undeniably intertwined with AI. As technology continues to evolve, AI will increasingly assist forensic experts, helping to unlock the mysteries behind unsolved cases and bringing justice to victims and their families. The incorporation of Artificial Intelligence (AI) within legal and investigative spheres has notably altered how evidence is collected, analysed, and presented. In India, the Bharatiya Sakshya Adhiniyam 2023 provides a legal framework regarding the admissibility of electronic records under Sections 62 and 63. 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.

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## Competing interests

The authors declare that they have no competing interests.

**How to cite this article (Vancouver)**
Sarma S. Forensic Science and Role of AI in It. CHEARS Chronical. 2026;13(4):e206. Available from: https://chears.in/journal/volume-13/issue-4/forensic-science-and-role-of-ai-in-it-206
Published in CHEARS Chronical. https://chears.in/journal/volume-13/issue-4/forensic-science-and-role-of-ai-in-it-206