ARTIFICIAL INTELLIGENCE IN FORENSIC SCIENCE: INVASION OR REVOLUTION?

BY

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ABSTRACT

Artificial Intelligence (AI) is a branch of software engineering; concerned with a computer process that can mimic human behavior and thought processes such as learning, reasoning, adapting, and self-correction. Forensic science involves the application of more effective scientific principles and techniques to investigate the crime and serve justice, demanding the cognitive examination of massive volumes of complex data. Thus, AI seems to be an appropriate technique for dealing with many of the current difficulties in forensic science. The present review provided an overview of AI, conversing its current and probable forthcoming applications in forensic science. For example, AI can be employed in DNA evidence, pattern recognition, crime scene reconstruction, digital forensics, image-processing, psycho/narco-analysis, ballistics, and satellite monitoring. Artificial Intelligence has limitless applications launching from the crime scene investigation to the day of Judgment. Intelligent software has simplified forensic investigations, explained the reasoning process that varies from one algorithm to another, and reduced the errors that may occur due to cognitive bias. However, every technology has some limitations; for example, intelligent systems require a giant database of knowledge, which may result in false-positive or negative interpretations if inputs are outside the trained data sets. Besides, this can raise some ethical and legal concerns. The blend of master and machine is needed to diminish the functioning load and understand more cases. Technology can make their job easier, but it will never be able to replace them. Because forensic science is an area of specialists, AI will only serve as a supplementary tool.

Keywords: *Machine learning; criminal investigations; Artificial Neural Network; forensics; digital evidence*

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TERMINOLOGY

I- Forensic Science

Forensic science is combined from two different Latin words: forensic and science. The former, forensic, relates to a discussion or examination performed in public, as trials in ancient Roman times were public. The second, science, is derived from the Latin word for 'knowledge' and is today closely tied to the scientific method, a systematic way of acquiring knowledge. Concurrently, forensic science means using scientific methods and processes to investigate the crime and serve justice ***(Gupta et al., 2020).***

II-Artificial Intelligence

Artificial Intelligence (AI) sometimes called machine intelligence is a machine's ability to show intelligence similar to that of humans and animals. This term frequently describes any machine which can sense its environment to perceive information and then take action according to the received data and imitate the "cognitive" functions of human minds, including but not limited to "learning" and "problem-solving" ***(Mitchell, 2010).***

III- Machine Learning (Learning Algorithm)

Machine Learning (ML) is a subfield of AI that aims to enable computer systems to draw inferences from a large quantity of data without being explicitly programmed. ML task is an abstract representation of the problem. For a prediction problem, it can be either a classification/ clustering or regression problem, depending on the type of target labels. Take age estimation as an example; if age is considered categorical, it can be defined as a classification task, while it could be a regression task if it is numeric. Machine learning and reliance upon AI in the courtroom are not new. For example, DNA testing and breathalyzer analysis, which depend on machine learning, are routinely admitted by judges. ML is a subfield of AI, while deep learning (DL) is a subfield of ML. **(Fig 1)** ***(Du et al., 2020).***

IV- Deep Learning

The term neural network is derived from the human brain, tha can learn from past experiences. An Artificial Neural Network (ANNs) is similar to that functioning of the human brain. Similarly, ANNs can learn from the training data sets, and map the resultant output to the input. The first artificial neuron was produced in 1943 by Neurophysiologist Warren McCulloch and the Logician Walter Pits. They can perform complex tasks, such as object classification and detection (Recognizing a particular pattern) ***(Nagi et al., 2020).***

V-Artificial Neural Networks

The term neural network is derived from the human brain, which is capable of learning from past experiences. An Artificial Neural Network (ANNs) is similar to that functioning of the human brain. Similarly, ANNs are able to learn from the training data sets, and there is a mapping of the resultant output to the input. The first artificial neuron was produced in 1943 by the Neurophysiologist Warren McCulloch and the Logician Walter Pits. They can perform complex tasks, such as object classification and detection (Recognizing a particular pattern) *(**Mitchell, 2010**).*

VI-Data Reconciliation

It is the process of data comparison to validate an action or a hypothesis. In post-mortem identification (forensic anthropology and odontology), data reconciliation means comparing post-mortem data against antemortem data to identify an individual ***(Tournois and Lefèvre, 2021).***

INTRODUCTION

Brief historical overview

The earliest significant study of AI began in the mid-20th century by Alan Turing, a British mathematician, known for breaking the German Enigma machine's encryption during the Second World War. Considered one of the founders of computer science and artificial intelligence, Turing was the first to introduce the ultimate goal and vision of artificial intelligence and hypothesized that machines could use the information to imitate humans in problem-solving and decision-making. A few years later, John McCarthy, a professor of mathematics, coined the term artificial intelligence. He defined AI as the science and engineering of making intelligent machines. However, there is no universally consensual definition of artificial intelligence as it is an interdisciplinary science combining multiple fields and approaches such as sociology, cognitive sciences, and mathematics ***(Rigano, 2019).***

In 2004, a wide range of intelligence methods was available to support law enforcement; for example, in crime analysis, the following emerged: crime pattern analysis, geographic analysis, investigative analysis such as network analysis, telephone record analysis, and bank record analysis, and in strategic analysis: the threat assessments, target profiles, and strategic targeting ***(Alzou'bi et al., 2014).***

Representation of Knowledge

In most AI programs, the principle is the interpretation of information (referred to in AI as knowledge representation) and ontology. Ontology is how to interpret the facts regarding which we want to argue and how we systematically arrange the knowledge representation so that we can reason about it. Knowledge interpretation can be about the properties of artifacts in the domain (information), how data can be interpreted (awareness of what rules and techniques to implement in a given situation), or even how definite processes (strategic or meta-awareness) are implemented ***(Mitchell, 2010).***

The creation of standardized international ontology for digital forensics would have obvious benefits. In multi-national cases involving multiple jurisdictions, this standardized ontology would provide a structured assembly for the digital proof examination and offer to perform a comprehensive and accessible case archive. Ontology can develop a routine and reusable set of context information and help assess the efficiency of professionals, whether human or artificial intelligence systems, and provide a practical tool for educating automated forensic practitioners that proved its effectiveness in many artificial intelligence areas ***(Gupta et al., 2020).***

- **Principles for application of AI in Forensic science**

Forensic science often requires the intelligent analysis of large amounts of complex data. Therefore, AI seems to be an ideal approach to deal with many problems occurred during practice in a realistic time frame ***(Mohsin, 2021).*** Simultaneously, in forensic science; seven principles should be considered: first; the law of individuality, second; Locard's principle of exchange, third; the principle of comparison, fourth; the principle of analysis, fifth; the principle of probability, sixth; the low of progressive change, and lastly; the low of circumstantial facts. The most basic principles of forensic science are Locard's principle of exchange which states that "when two entities come in contact with each other, they leave a trace on each other". This principle is fundamentally responsible for the basis of forensic science and criminal investigations and also, for AI use in the sense that even a pattern will be enough to identify the suspect and help to perform the proceedings from a crime scene to courtrooms ***(Hamlin, 2021).***

Explaining the reasoning process

A critical issue for AI applications in the forensic arena is the ability of the AI technique or algorithm used to explain the reasoning process. AI techniques are divided into two categories; symbolic (those that reason with discrete entities in a knowledge base) and sub-symbolic (those where the knowledge is spread around the representation structure). One of the most common types of symbolic reasoning is the expert system. Expert systems follow a predefined rule and consistently have a limited strategy for choosing which one to use at any time. Expert systems can, therefore, at any point, explain the reasoning for the conclusions obtained ***(Mitchell, 2010).***

1-Applications

Since the last decade, applications based on artificial intelligence have emerged in forensic practice to support, augment, or replace forensic experts in routine duties. While, others could enhance or create new tasks in daily practice. However, some may not be mature enough to date to be used in actual conditions due to a lack of validation experiments ***(Tournois and Lefèvre, 2021).***

AI models should not be transferable from one application to another without expertise in both applications. For example, AI applications used for postmortem purposes may not be relevant for antemortem purposes. Postmortem identification aims at finding elements to associate a body or its remains with an identity. To do so, forensic experts currently use non-comparative or comparative approaches. The non-comparative strategy depends on inferring or determining individual characteristics to establish the identity of subjects, while the comparative approach aims to compare antemortem and postmortem data to search or confirm their identity ***(Pathak and Narang, 2021).***

AI was mainly used to estimate personal characteristics such as age, gender, stature, height, weight, and body mass index, in a non-comparative approach. Most AI applications used for that approach were designed to estimate the age or gender of an individual from imaging techniques used in traditional forensic medicine. Indeed, age and gender were mainly determined from radiographs, and new developments take advantage of magnetic resonance imaging techniques for gender determination from brain features. Some AI applications were also developed for facial reconstruction purposes from odontology data. In comparative approaches, AI applications were used to label data or perform data reconciliation between antemortem and postmortem data. Therefore, applied AI research in forensic anthropology and odontology was carried out ***(Tournois and Lefèvre, 2021).***

1.1 Criminal investigations

Artificial Intelligence has effectively made its grand entrance into a criminal investigation. Forensic investigation entails conducting an extensive study, gathering information from many sources then integrating them to reach logical conclusions. While extracting such data from mysterious sources may be fruitful and intriguing, dealing with enormous amounts of data can frequently be confusing and chaotic. During an investigation, AI can assist forensic

specialists in properly managing data and meta-analysis at multiple levels. This may save forensic investigators a significant amount of time to focus on other vital duties. Al technology made the acquired data freely available to the involved parties and used it to prepare data repositories so that it may be accessed at any moment as needed ***(Mohsin, 2021)***.

According to ***Kamdar and Pandey (2011)***, AI can be a great tool in many expects like:

i. Data analysis and availability to support the investigation.
ii. Addressing well-scoped problems and methodology for cases.
iii. Pattern recognition.
iv. Explaining the reasoning process well.
v. Reducing the level of false-positive or false negatives during analysis is very common in forensic science.
vi. Formally structuring the representation of knowledge will also help the legal community in fast and accurate solutions.
vii. Having a well-organized performance evaluation.
viii. Data mining and knowledge discoveries.
ix. Building statistical evidence.
x. Integrating with current architecture, tools, and applications.

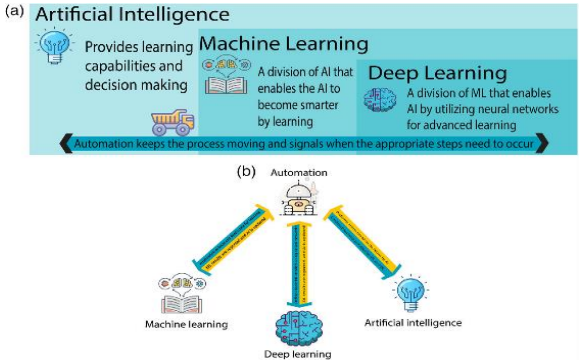

Figure (1): The relationship between automation, AI, and ML/DL. *(Jarrett and Choo, 2021).*

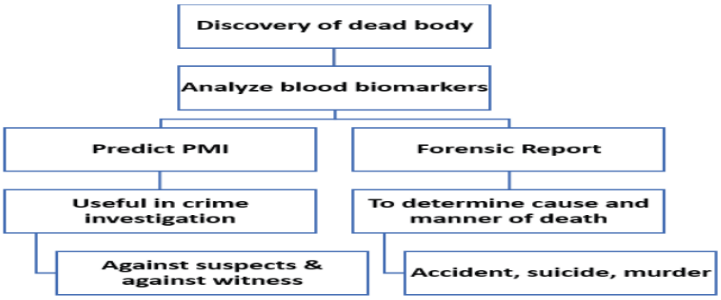

Figure (2): Showing application of machine learning to predict post-mortem interval *(Pathak and Narang, 2021)*

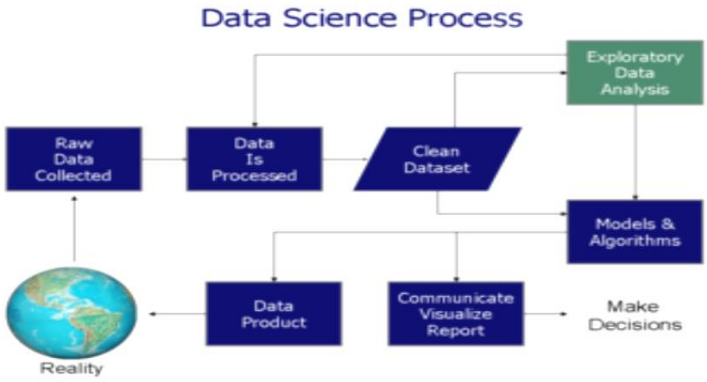

Figure (3): Flow diagram of data processing *(Gupta et al, 2020)*

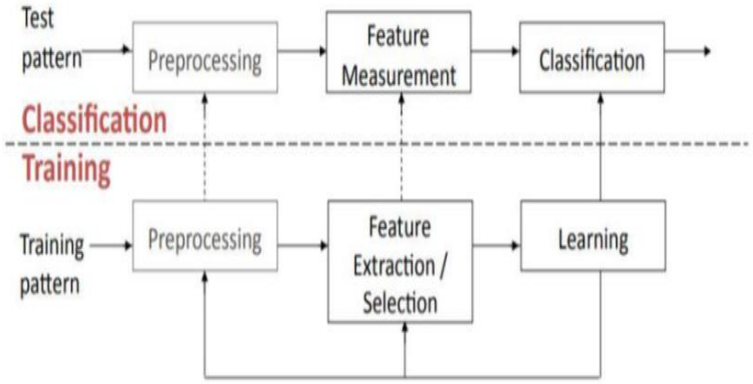

Figure (4): Flow Diagram of Pattern Recognition *(Gupta et al, 2020)*

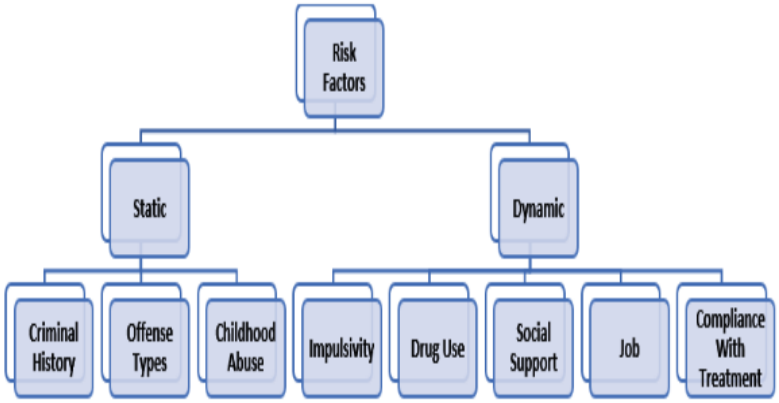

Figure (5): Flowchart showing risk factors associated with forensic psychiatry *(Pathak, and Narang, 2021).*

1.1.1. Crime Scene Reconstruction

This system required some inputs like the presence of any object at the crime scene e.g. a dead body or any object like a glass piece. After extracting and analyzing each aspect of input, it will try to figure out three to four animated videos on its own that could be of great help to forensic experts compared to the manual construction of animated crime scenes ***(Bruno et al., 2009)***.

1.1.2. DNA Evidence

Biological material, such as blood, saliva, semen, and skin cells, can be transferred through contact with people and objects during the commission of a crime. As DNA technology has advanced, so has the sensitivity of DNA analysis, allowing forensic scientists to detect and process low-level, degraded, or otherwise unviable DNA evidence that could not have been used previously. For example, decades-old DNA evidence from violent crimes such as sexual assaults and homicide cold cases is now being submitted to laboratories for analysis. As a result of increased sensitivity, smaller amounts of DNA can be detected, which leads to the possibility of DNA detection from multiple contributors, even traces. These and other developments are presenting new challenges for crime laboratories ***(Rigano, 2019).***

DNA analysis software was first developed a decade ago. Delicate procedures created in recent years imply that police would now be able to distinguish minute hints of DNA "touch DNA" at a crime location or on a piece of proof**.** ***(Pathak and Narang, 2021).***

Researchers have created algorithms to isolate this DNA soup and to gauge the overall measures of every individual's DNA in a sample. These "probabilistic genotyping"

techniques have empowered scientific agents to demonstrate how likely it is that a person's DNA was remembered for a blended sample found at the crime location. DNA analysis produces large amounts of complex data in electronic format; these data contain patterns, some of which may be beyond the range of human analysis but may prove useful as systems sensitivity increases. Also, presently, more modern AI may have the potential to address this challenge. ***(Rigano, 2019).*** AI strategies were created trying to separate DNA profiles and attempted to work out whether a DNA test came straightforwardly from the person of interest (POI), or whether it had recently been guiltlessly moved into the crime scene. ***(Marciano and Adelman, 2017).***

1.1.3. Forensic Odontology

Forensic odontology mainly deals with unknown individuals' identification through their remains (teeth and jawbones). It has become an integral part of forensic science in the identification of deceased individuals who cannot be identified visually or by other means after mass disasters or crimes. Advanced calculations of AI are implemented for individual distinguishing proof through dental findings during mass disaster investigations. Also, they can likewise be prepared to assess the sex of a person from skeletal remains. AI calculations dependent on neural organizations require no critical mastery to carry out. They are exact, fast to utilize, and have a capacity to dispose of human predisposition from sex assessment of skeletal remains. In forensic odontology, AI is mainly used to classify dental restorations and cusps or for feature extractions. These records can be used as elements to compare between antemortem and postmortem data ***(Khanagar et al., 2021).***

1.1.4. Three-Dimensional Facial Reconstruction

Facial reconstruction is the recreation of an individual face space (with an unknown identity) from their unidentified cranial remains. This capacity to produce an individual's face space empowers the expert to consolidate earlier information like assessment old enough and weight straightforwardly into the reconstruction. This framework can depend on a data set of CT head scans if it is the lone data set of this extent in the presence. In forensic anthropology, AI is applied for craniofacial superimposition, especially during the skull-face overlay stage where skull models are superimposed to face photographs to identify an individual ***(Tu et al., 2007).***

1.1.5. Fingerprint

A fingerprint is an impression left by the friction ridges of a human finger. In the field of fingerprinting and determining its patterns, the Desorption Electrospray Ionization Mass Spectrometry Imaging (DESI-MSI) technique was applied to estimate latent fingerprints according to the chemical patterns and structures. At the same time, the classification algorithm was used in the Gradient Boosting Tree (GDBT) machine learning model, which enabled the classification of the standard samples of the study to determine gender, race, and age by fat. This model could differentiate and classify trained fingerprint samples until the system could identify the unknown ones and determine the age, gender, and race through the sweat components. This method could offer significant forensic value by using the results of mass spectrometry with machine learning, allowing the identification of personal information of people at crime scenes inexpensively. It may take forensic science to another path in identifying people at crime scenes according to their metabolites ***(Zhou and Zare, 2017).***

1.1.6. Post-mortem interval

The Postmortem interval (PMI) is the time since death. This PMI and forensic report will help the court, regardless of whether to acknowledge or dismiss the assertions of suspects and witnesses. The idea of assessing the time since death during forensic examination depends on the utilization of an AI device that estimates markers in the blood; for example Lactate dehydrogenase (LDH) and Aspartate aminotransferase (AST) as protein and cholesterols as lipid, as well as the pH of the blood. When the profile is given to the device, it will examine the information and gives the right outcome with the prediction of the time of death. Data processing is the principle utilized for understanding information and data set examination to assess the PMI.

Providing a profile to the AI machine and getting the ultimate yield is the solitary interaction **(fig.2)** ***(Mesejo et al., 2020).***

1.1.7. Forensic Ballistics and Gunshot detection

Forensic ballistics involves the examination of evidence from firearms that may have been used in a crime. When a bullet is fired from a gun, the gun leaves microscopic marks on it and the cartridge case. These marks are like ballistic fingerprints. Artificial Neural Networks will guide experts on where to search for gunpowder and cartridge cases and compare bullet marks and other evidence with the database itself with the help of image processing without any manual interference. Scientists have developed algorithms using a well-defined mathematical model (Automated Ballistics identification system). These algorithms can detect gunshots, differentiate muzzle blasts from shock waves, determine shot-to-shot timings, determine the number of firearm weapons present, assign specific shots to weapons and estimate probabilities of class and caliber. All of which could help law enforcement in investigations ***(Bobbili et al., 2020)***.

1.1.8 Toxicology and drug analysis

Utilizing chemical databases, expanding search scope, and linking to millions of compounds will be future solutions to identify narcotic compounds, abused drugs, and their various metabolites in criminal forensic samples. Automated chemical analysis techniques have enabled the identification of materials and their qualitative and quantitative composition, the availability of a great wealth of information that reached by the year 2020 more than 160 million organic and inorganic substances registered in the Chemical Abstract Service (CAS) database. This extensive data may lead to research difficulties and time overload to reach the target information. The accumulated data resulting from scientific research are impossible to be managed except by implementing computer methods and artificial intelligence tools to build massive experiences from this data ***(Gasteiger, 2020).*** The growing chemical data and its linkage with information technology and digital computing resulted in the development of modern scientific disciplines such as chemical informatics. This discipline contributed to conducting calculations to solve chemical equations and theories and predict the products of reactions, developing statistical methods for analyzing chemical data, and helping in the analysis of compounds and spectra. For example, statistical methods can identify compounds and their pattern through spectral comparison with databases ***(Dotzert, 2021)***.

Machine learning models provide a new dimension for identifying the patterns of chemicals in a mixture by distinguishing compounds according to composition, knowledge of analytical conditions, and other information such as chromatographic separation results with separation information such as mobile phase and separation column and mass spectrometry results ***(Gasteiger, 2020)***.

1.2 Data Acquisition and Recovery Purposes

One of the early stages of a digital investigation is making the digital evidence available in a human-readable form (extraction). This includes extracting information from known file systems and file types and recovering deleted data. Files deleted within a file system may be recoverable deterministically if some metadata remains ***(Du et al., 2020).*** Generally, cyber forensic experts come across a major problem in analyzing a file (which file is significant can be decided only after accessing/opening that file). Another problem is; that if the suspect has changed the file extension, say from .doc to .exe. These problems become a very tedious job. To eradicate these two problems, ANN internally analyzes the files and will display only content appropriate to the expert ***(Turner, 2005).***

1.3 Cyber Forensics

In crimes performed over an internet network, ANN can tell us the activities of a web surfer who is surfing legally or illegally. In investigation matters like phone call tracing and other activities, police and forensic experts face a political problem. To eradicate this problem, ANN will decide which phone calls to trace and which not

through its pattern recognition system through remote sensing and satellite facilities. Also, pattern recognition for serial killers will be easier and enable forensic experts to solve cases very soon enough ***(Kamdar and Pandey, 2011).***

1.4 Data Discovery and Analysis

Digital forensics is a highly computationally emerging area involving the study of large and dynamic data sets. Data mining and knowledge discovery require the use of AI. Data mining is a combination of AI, statistical analysis, and probabilistic methods; used to collect and analyze giant data. Artificial Intelligence is a suitable method for managing and solving these broad data sets because ordinary computational methods may not prove effective. During data mining, the user may ask for certain files to be highlighted that contain specific information and relation to the user. This can aid in the process of pattern recognition. AI can also help avoid obvious patterns and focus on that of relevance ***(Mitchell, 2010; Mohsin, 2021).***

Digital forensic science concerns the recovery of evidence from a digital device. Artificial Intelligence, for example, may be used to do a meta-analysis of meta-data obtained from multiple outlets and pool them to simplify complex data. AI displayed data in a short period in a more simple and understandable format ***(Costantini, 2019).*** Digital forensics applies science to maintain a strict chain of custody during the identification, collection, examination, and analysis of digital data while preserving integrity. Additionally, with the widespread adoption and proliferation of electronic appliances, much of the evidence of non-cyber-related criminal activities is found on cell phones, computers, or other digital devices ***(Jarrett and Choo, 2021).***

1.5 Pattern recognition

Techniques are concerned with the theory and algorithms of putting abstract objects (e.g, measurements made on physical objects) into categories. One of the key aspects of forensic science is the detection of different forms of trends in a large data set. Recognition of trends depends upon solid evidence and probabilistic thinking. Artificial Intelligence can become more effective in the identification of these trends in complex data. This may include the identification of picture patterns where the algorithm attempts to recognize different sections of a picture or an individual, detecting patterns in a letter, such as email messages or patterns in a sound recording. Pattern recognition techniques will aim to fit all potential data types to obtain a high degree of performance. This is hard to do in reality. So, techniques of machine learning or artificial intelligence are employed, with the advantage of reducing the degree of false positives or false negatives **(fig.3, 4)** ***(Bishop, 1995).***

1.6. Providing legal solutions

Forensic reports provide statistical tools for the judicial system to analyze facts. For a more comprehensive and detailed collection of knowledge, AI provides quick decisions to the legal community when required with more complex and extensive information databases. AI will show events in graphical structures that can be used to express scenarios and also support probabilistic reasoning. AI can also give simulation models that will help augment lawyers and judgment from the judges. AI helps different judges evaluate the information for a particular judgment ***(Mohsin, 2021).***

1.7. Building statistical evidence

Forensic science involves supporting the narrative and arguments with impressive statistical evidence. AI can build graphical structures that can support building scenarios and case stories. It can also help assemble graphical model situations that can be used to prove or disprove arguments, helping the law make better judgments. AI provides mathematical and computational tools that can help to build statistically relevant and significant evidence. All this will reduce the errors and improve the understanding of the statistics behind a study ***(Mitchell, 2010).***

1.8. Improving communication

The forensic investigation involves contact among forensic statisticians, attorneys, police investigators, and others. Miscommunication between such parties can contribute to misinterpretation of data or incorrect decisions leading to delayed or inaccurate justice. Artificial Intelligence can

provide new algorithms to bridge this coordination gap between the numerous stakeholders in this region. AI algorithms can support argumentation and narrative-based communication with statistical evidence and build justice on AI based argumentation and scenario construction **(*Kamdar and Pandey, 2011).***

1.9. Creating repositories

Artificial Intelligence will also help create an electronic archive that can hold all the digital forensic operations, records, assets, and reports. With the increasing pace of storage capacity expansion, like USB, hard drives, optical media, and flash drives which can hold massive volumes of information, it is becoming more challenging for forensic science researchers to keep and examine all this information. Artificial Intelligence may be a feasible resource for legal purposes to store, interpret and use such data ***(Gupta et al., 2020).***

1.10 Neuroprediction and Psychology-analysis

Risk evaluation is a vital part of the criminal equity framework. Lately, there has been a developing interest in advancing new devices and strategies to improve the field of risk assessment in forensic psychiatry and criminal justice. The principle of these techniques is to distinguish high-risk and low-risk offenders correctly. Depending upon the purview, these strategies are utilized to advise regarding medico-legal choices, for example, concerning condemning, parole, public responsibility, capital punishment, disposition in juvenile courts, and discharge following findings of insanity **(fig.5)** ***(Conroy and Murrie, 2008).***

ANN can be utilized to improve the prescient accuracy of risk assessment. Al can analyze the activities undergoing the suspect's brain during brain-imaging and brain-reading strategies to distinguish dangerous offenders. Theamount of narco-drugs will be decided by ANN after analyzing what amount of drug will produce the required effect. The utilization of calculative risk assessment has developed alongside the exploration in the field of neuroimaging, prompting the advancement of brain-reading strategies. The potential legal utilization of the procedure is to distinguish dangerous offenders. Furthermore, neuroimaging has developed what can be called A.I-Neuroprediction, which is the utilization of primary or functional brain parameters combined with AI strategies to make clinical or behavioral predictions ***(Richmond et al., 2012).***

1.11. Crime forecasting

Predictive analysis is a complex process that uses large volumes of data to forecast and formulate potential outcomes. This work is time-consuming and subject to bias and error. Violence reduction strategies can be implemented with the aid of AI. Volumes of information on the law and legal precedence, social networks and media can be used by AI to suggest rulings and identify criminal enterprises resulting in predicting and revealing people at risk from criminal enterprises. The algorithms can determine the victim, perpetrator, and environmental factors that distinguish between financial exploitation and other forms of elder abuse ***(Rigano, 2019)***.

1.12 Public safety video and image analysis

Video and image analysis is used in the criminal justice and law enforcement communities to obtain information regarding people, objects, and actions to support criminal investigations. However, the analysis of video and image information is very labor-intensive, requiring a significant investment in experts. AI technologies overcome such human errors and function as experts. Traditional software algorithms that assist humans are limited to predetermined features for facial recognition or demographic information for pattern analysis ***(Shah, 2018).***

AI video and image algorithms can determine independent complex facial recognition features/ parameters for accomplishing difficult tasks. These algorithms have the potential to match faces and identify weapons and other objects. Video analytics for integrated facial recognition, detecting individuals in multiple locations via closed-circuit television or across multi-cameras, and object and activity detection could prevent crimes through movement and pattern analysis, recognize crimes in progress, and help investigators identify suspects. With technology such as cameras, video, and social

media generating massive volumes of data, AI ensures more public safety, thus increasing community confidence in law enforcement and the criminal justice system ***(Rigano, 2019)***.

2-Risks of Artificial Intelligence use

AI is not yet a mature technology in many of its applications. Criminal justice, and primarily law enforcement, should then consider the use of AI not only in light of fundamental human rights principles such as privacy and non-discrimination but also in light of the growing belief that AI algorithms are more objective and intelligent than humans when in fact they can convey human error ***(Muller, 2020).***

- **Bias**

Although AI systems exclude any human intervention, it is created by humans, and in such regard, it implies a room for error. All datasets introduced in AI algorithms to generate results are human data, which means they already contain human bias, which then can pass on to AI outcomes ***(Babuta and Oswald, 2009).***

- **Discrimination and human rights in fringement**

Independent research reports show that using AI can lead to particular groups of people being more frequently stopped and searched by law enforcement than others, depriving citizens of fairness and equity principles. For example, AI surveillance of criminal 'hotspots' can increase geographical discrimination because these areas are more controlled by police than other areas, resulting in higher arrests in such AI-monitored areas. It is critical to underline that databases used by law enforcement are private companies, such as Clear view, the world's largest facial network company created for law enforcement use. Although Clear view is contractually bound to governments, it implies a partial transfer to private companies, which could lead to other adverse outcomes, such as a poisoned database or cyber piracy, which would infringe privacy rights principles of hundreds of thousands of citizens ***(Raso et al., 2018).***

- **Need for regulation**

The use of AI in law enforcement implies a high level of accountability, fairness, and transparency. As a result, the European Commission has understood this by proposing on 21 April 2021, the Artificial Intelligence Act to codify the high standards of the EU trustworthy AI paradigm, which is required for AI to be 'legally, ethically and technically robust, while respecting democratic values, human rights and the rule of law'***(Artificial Intelligence Act, 2012).***

3- Ethical and legal challenges of artificial intelligence

Ethical challenges of AI include four primary challenges: (1) informed consent to use, (2) safety and transparency, (3) algorithmic fairness and biases, and (4) data privacy. Legal challenges of AI focus on (1) safety and effectiveness, (2) liability, (3) data protection and privacy, (4) cyber security, and (5) intellectual property law ***(Gerke et al., 2020).***

From a medicolegal perspective, the main risk is that of re-identification. Indeed, personal health information can be used for unlawful purposes (for instance, a genetic predisposition to a disease can be used to increase the cost of insurance coverage) or to obtain more sensitive information (e.g., some genetic markers can be used to predict externally visible characteristics of the individual like the skin tone and the color of the eyes) ***(Oliva et al., 2021).***

Artificial intelligence needs big data to develop reliable predictions. Data protection has become even more critical since the beginning of the pandemic: the processing of big data was (and still) used to enhance the COVID-19 control measures (e.g. through contact tracing and risk prediction algorithms) by adopting two different approaches: some nations adopted the data-first approach (in which storage and communication to health and research institutions of the data represent the priority), while other nations selected the privacy-first attitude (in which health authorities do not know individual movements and interactions). In any case, each country is storing an unprecedented amount of population data of every kind (e.g., health data, individuals' movements, and interactions) that, if not properly processed, could lead to catastrophic outcomes ***(Fahey and Hino, 2020).***

Therefore, cyber security should still represent a priority ***Morley et al. (2021)*** have documented that an application for tracking and tracing COVID-19 cases can be considered ethically justifiable only if it complies with high-level principles (necessity, proportionality, scientific soundness, and time-boundedness) and enabling factors like the use of the application is voluntary, consent is requested, stored data can be erased upon users' request, its purpose is defined and limited) ***(Oliva et al., 2021).***

Besides the risk of data misuse, AI systems are vulnerable to both software and hardware faults, which can be extremely harmful to patients. For instance, inadequate training data or wrong design choices can cause abnormal system behavior. These errors can be due to the users rather than the developers. For example, an AI system can make wrong (and potentially harmful) decisions if not used in the original design context. Moreover, logic, memory, or communication components of the devices can be affected by permanent or transient hardware failures (like the temporary failures, also called "soft errors" represented by bit flips due to radiation particles) ***(Athavale et al., 2020).***

Artificial Intelligence and forensic expert testimony

Artificial intelligence is a technological development that will inevitably impact the law and the forensic expert witness. A forensic expert is essential for the successful prosecution of cases. They have to ferret the valid data from the bad, which can be expensive and time-consuming. AI usage may offer a more efficient means to carry out that task. Consequently, courts, practitioners, and forensic experts will need to adapt to the emerging technology and understand how it will be utilized by a jury in making decisions. AI has its positive uses, but only a human expert can perform that unique, psychological connection with the jury ***(Metallo, 2019).***

CONCLUSIONS

Artificial Intelligence has been in operation for less than 50 years, yet numerous applications and techniques have been achieved in forensic science. Artificial intelligence helps experts handle large and complex data effectively and perform analysis much faster at various levels during an investigation. Cautious handling of this data is also crucial, as it ensures the collected information is stored, analyzed safely, and accessible to only stakeholders. Technology has made its way into the legal system. There is no question that AI will transform the forensic professions as it will the courts while making its way into the legal system. AI programmers are concerned more with "replicating human abilities" through "pattern recognition" or "machine learning" rather than a deliberative process. The principal strengths of machine learning versus human learning are: that machines can process large amounts of data, find weaker or more complex patterns and work better in less predictable environments. Also, machines can be more consistent decision-makers because they are less susceptible to cognitive bias. On the other hand, major weaknesses include: a lack of model flexibility, not all problems have the correct data to learn, data can reflect bias in the real life, and not every problem can be solved with mathematical analysis, which is the only output with machine learning applications; and other considerations must be "factored into decisions," including privacy issues, that AI may not be able to address the same way humans can. Yet, AI has its positive uses, but only a human expert can make that unique, psychological connection with the jury. AI, however, should not replace the human expert opinion and human judgment as to legal liability because AI and humans arrive at conclusions differently. AI has tremendous potential for improving forensic science practice, but its potential can be only unlocked by starting to address the ethical and legal challenges facing us.

RECOMMENDATIONS

- It would therefore seem that AI is an ideal approach to deal with many of the problems that currently exist in forensic science. However, like any immature technology needs time and mistakes to progress.

-The implementation of AI in forensic science is not a trivial process. Indeed, the AI-based applications produced during the research stages require further validation studies with

more standard data to be employed in realistic and operational environments.

-Moreover, forensic experts may be reluctant to use AI in daily practice due to ethical, professional, and AI-inherent issues, such as biases and the lack of elements of AI interpretability in specific applications. So, international consensus is needed to recognize the social risks implied by artificial intelligence, explain, educate, and boost transparency, adapt training and education to the new AI society, regulate and improve data processing, build bridges and enhance communication.

-Finally, AI is a thriving field in which techniques are constantly improved, and the potential of AI for forensic science purposes is not fully exploited to date. AI applications in forensic science are promising data-driven tools that could enhance forensic practice. So, further research projects involving AI should be conducted to develop more applications.

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