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Artificial Intelligence for Forensic Medicine

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Abstract
Artificial intelligence (AI) is expanding into all aspects of daily work for identifying and predicting criminals, suspects, business, health, space, agriculture, and judiciary works. Consequently, applying AI to forensic medicine has grown the interest of researchers in the recent past. This paper explores the utility of AI in the fields of Clinical Forensic Medicine and forensic pathology. Different applications use AI to address a variety of challenges presently experienced by forensic scientists. The AI-trained algorithms generate reports that assist forensic reasoning by presenting reliable information and compelling legal proof after analysing a large amount of raw data. Therefore, accuracy and reliability are primary concerns in such systems. The adaption of AI in forensic medicine is challenging for various reasons, such as training requirements for medical practitioners, biases due to ethnicity and limitation of the dataset, and validation of the developed algorithm. This paper discusses the above challenges in detail and presents algorithms which perform well for different forensic applications.

Keywords: Artificial intelligence, forensic medicine, forensic pathology

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Introduction

A range of professionals, include. ing Doctors, technicians, police, investigators, judges, anthropologists, dentists, criminologists, and other specialists, are involved in the investigation that examines and diagnoses people who have been hurt or who have passed away due to external or unnatural causes. These reasons can be categorised as poisoning, assault, suicide, or other types of violence., and then apply their findings to the law, collectively referred to as forensic medicine.[1] Its primary purpose is to provide an analysis report for law agencies for face recognition, age and sex identification, DNA analysis, post-mortem interval estimation, etc.

Conventional forensic medicine uses human knowledge and materials to investigate the incident. However, these methods are complex and time-consuming, which may lead to human fatigue and incorrect conclusions. Further, the court will raise critical questions regarding the accuracy and validity of the analysis result. Furthermore, the increase in

forensic work and the low number of in-house forensic professionals have become a massive problem in Sri Lanka. Due to these reasons, applying Artificial intelligence (AI) to forensic science has become an attractive proposition and a significant body of research has been conducted over the years.

AI is simulation of human or animal intelligence processes by computer systems. Machine Learning (ML) and Deep Learning (DL) are two subsets of AI which attempt to do the above simulation. ML is used to learn from structured data to predict an outcome, while DL is used for highly complex problems with unstructured data. As a whole, AI-powered algorithms are capable of pattern recognition, Natural Language Processing (NLP), object identification, decision-making, and making future predictions. Further, these intelligent machines or agents are used in applications such as intelligent transport, healthcare, agriculture, security, etc.

Expectedly, AI is making its way into forensic science. However, the majority of applications of AI can be found in the field of digital forensics. Areas of forensic science, like latent print analysis, blood spatter pattern analysis, forensic anthropology, and ballistics, to name a few, are trying to apply AI as well. Forensic medicine is the main branch of forensic science.[1]

AI has shown a significant improvement in healthcare in a generation. Indeed, AI is applied in forensic medicine in many ways. Therefore, this research focuses on identifying novel techniques for practical use in forensic medicine using image analysis methods in deep learning.

Objectives

The main purpose of this paper is to

1. analyse the current usage and the trending methodologies of AI in Clinical forensic medicine and Forensic Pathology
2. discuss the present challenges faced by forensic medicine practitioners.

Discussion

(1.1) Use of Artificial Intelligence (AI) in Clinical Forensic Medicine

Clinical Forensic Medicine is the term used to describe the area of medicine that deals with interactions in the judiciary, police, and the law involving living people. Unfortunately, a lack of research has been published on AI in Clinical Forensic Medicine in the recent past.

Biometric recognition is a revolutionary finding back in the day for correctly and uniquely identifying persons in forensic medicine. However, investigators collected fingerprints for various requirements from the previous century, which are not immutable due to the aging process. Identifying a person from low-quality or partial fingerprint images is a challenging proposition. Deep learning technologies such as Autoencoders and Generative adversarial networks (GANs) are used to identify persons from low-quality fingerprints in forensic medicine.[2] Autoencoders and GANs are both useful techniques for such situations as they are adept at creating missing information based on previous data and context.

Some other studies analyse the correlation with the sex of an individual using Discrete wavelet transform (DWT) and Singular value decomposition (SVD) to detect the sex of fingerprints owner using AI technologies.[3]

Some studies focus on applying AI for diagnosing drowning. Diatom analyses have frequently been used in forensic practice to make the diagnosis of drowning. Zhou et al., proposed using a traditional chemical digestion method and AI-based system to detect diatoms automatically by training Convolutional neural network (CNN) models.[4] CNNs are network architectures that directly learn from the data, and it helps find image patterns to identify objects or classify them. This would help doctors to make efficient decisions in future intelligent diatom examinations.

Furthermore, despite patterns that can identify differences between consensual and non-consensual sex, it is still difficult for medical professionals to determine the relevance of genital lesions in confirming a legal rape charge. AI methods can use to examine sexual assault and diagnose rape in these situations.[5]

Afrianty et al., proposed a Back propagation neural network (BPNN) for sex determination. These methods compare the previously suggested Discriminant function analysis (DFA).[6] The suggested methods achieved better average accuracy than the DFA method. However, the DFA method achieved 100% accurate detection of a young male.

The age estimation has widened considerably in forensic medicine. Most current multifactorial age estimation techniques rely on radiography and mostly use the hand and wrist region. Another standard method uses computed tomography scans of the clavicles and panoramic dental X-rays. Presently, magnetic resonance imaging (MRI) is used to sidestep the disclosure of ionising radiation.[7] A multiple linear regression AI model was used to estimate the individual's age as a function of the variable for measuring age by using gender and wrist bone measurement. Multiple linear regression is a statistical method that employs two or more independent variables to forecast the results of a dependent variable.

The face identification AI program recognizes the individual’s face and predicts their age. In addition, Deep convolutional neural networks (DCNN) can be effectively used for age and sex detection, giving high efficiency in comparing the traditional age and sex predicting methods.[8] This will minimise the time of doctors and other technical personnel that involvement in forensic medicine. On the one hand, researchers need a good enough number of accurate datasets to train these algorithms to obtain better results.

Furthermore, skeletal remains are used to recognize the biological profile of unknown remains. However, it is difficult to sex determination from uncompleted, burned, or damaged remains. Therefore, AI-based Three-dimensional convolutional neural networks (3D-CNN) apply to forensic medicine’s clinical aspects for biological age and Sex determination.[9] Further, this is used to the prediction of Automatized 3D cephalometric landmark annotation areas and Soft-tissue face prediction from the skull and reversed and Facial growth vectors prediction.

(1.2) Use of Artificial Intelligence (AI) in Forensic pathology

This section discusses the present trend of using AI to determine the cause of death by examining a corpse. Post-mortem computed tomography (PMCT) is an ancillary investigation in forensic pathology and mainly scans the human head and torso. Clinical computed tomography (CT) is another imagery method used to diagnose muscle and bone disorders and fractures; this imaging differs from PMCT imagery. In addition, modern AI technologies are used for screening and computer-assisted diagnostics. However, applying it to radiological images is more challenging because the information is not a discrete dataset. Furthermore, CNN is commonly used in image classification works, thus, in radiology images.[10] Nevertheless, in post-mortem images, AI has demonstrated efficacy as a screening tool and even an alternative to autopsy. In addition to 2D images, Medical (CT) data provide 3D in nature and require 3D volumetric segmentation and study. In addition to 2D images, Medical (CT) data provide 3D images requiring 3D volumetric segmentation and study. These images use fracture detection to detect pathologies, such as skin anomalies and cancer in post-mortem imaging.

In forensic investigations, correctly identifying the post-mortem interval (PMI) or time of death is crucial. Therefore, forensic examiners must accurately estimate the PMI since it is crucial. With the introduction of AI, PMI can predict by providing blood samples. Therefore, these biochemical indicators proved significant instruments in forensic death investigations.[11] Furthermore, Biological fluids like blood and urine can be used in biochemical technologies to identify PMI estimation. Another study concept proposed an AI-based device for forecast the PMI by measuring the blood's profile of several metabolites, such as triglycerides, cholesterol, lactate dehydrogenase (LDH), and aspartate aminotransferase (AST).[12]

Moreover, natural or man-involved disasters happen in the world. Therefore, confirming the identity of the victims from the dead bodies is another challenging task for Forensic pathology. In order to identify deceased people, AI systems will be employed in Japan for the automated analysis of panoramic X-ray images in dental data. Japan, reflecting on the fact that the collected electronic dental and medical record data in a unified format was uploaded to the system.[13] This information will be effectively used in a disaster situation to identify the victims quickly.

Identifying the cause of death is the main task of Forensic pathology, from examining external or internal features in the dead body. Few AI-proposed studies have been conducted in this area to help medical doctors to identify the root cause. In addition, some studies use AI autopsy imaging to collect information from the family's narrative members through interviews to investigate the cause of death.[14]

(2) Challenges faced by forensic medicine practitioners

An expansive demand for AI applications in varying fields led to the development of various algorithms for prediction and support for decision-making. For example, AI has been used in forensic medicine. However, these methods encountered practical challenges in real-time applications due to selecting the appropriate algorithm, ability to solve some simple problems, speed, sizes of samples not sufficient for training, diversity, and complex relationships. Fang et al. discuss the challenges of machine learning and deep learning approaches.[15]

Machine learning and AI technology are proposed to use and implement in Forensic Medicine. However, the decisions given by the AI model may need to account for why certain decisions or predictions are being made.

Further, to apply AI models, forensic medical practitioners must need special training to evaluate their findings. However, some implementations of AI use dense neural networks, referred to as "black box" models. In this situation, Explainable artificial intelligence (XAI) use and can tell why a particular prediction is made, and it is essential to produce the evidence in Forensic Medicine.

Furthermore, forensic doctors may be reluctant to use AI technologies in daily practice due to bias-related issues. For example, criminal recognition systems perform worse in recognising the faces of women and Black individuals. In addition, as indicated by symptoms of uncontrolled illnesses, black patients are significantly sicker than White patients. Indeed, this is because the AI model was developed based on a dataset limited to particular events.[16]

AI algorithms are only developed for some forensic medicine-related areas, which is expanding. Recent advancements in AI, such as deep learning techniques, are the main inspiration for most research works on AI in forensic medicine. Therefore, applying the resulting AI applications in practice might be too early due to a lack of validation tests.

Conclusions

In forensic medicine, a wide range of professions have participated in taking decisions in the justice system. Modern AI benefits the justice system in many ways, such as video and image analysis processing, chemical analysis process, and other prediction using forensic information. Furthermore,

the image and video analysis process may be challenging for officials requiring extensive work hours, which may lead to human error and could have many implications for cases in the criminal justice system. However, human error can be minimised by applying machine and deep learning techniques.

Moreover, AI has been applied in Clinical Forensic Medicine in crime scene investigation by finding biometric recognitions of persons and examining sexual assault and 'diagnosing' rape cases, medical treatment, and age estimation using image analysis.

Another aspect is using AI in forensic pathology to identify the root cause of death, examination of the evidence, Post-mortem interval (PMI), and other important aspects related to judicial findings.

Regarding post-mortem investigation CNN, C3D deep learning algorithms use fracture detection to detect pathologies, such as cancer and skin anomalies in post-mortem imaging. Nevertheless, it is understood that this innovation must be addressed due to strong predicting capabilities and not to be ignored in forensic medicine.

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