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Application Of Artificial Intelligence And Machine Learning In Forensic Medicine – A Scoping Review

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Abstract

The rise of Artificial Intelligence (AI) will mark the next stage in the industrial revolution. All domains of medical science will be changed by the application of AI and Machine Learning. This review article intends to emphasize the existing potential for utilizing AI in modern forensic medicine, as well as the benefits and drawbacks of its application. The implementation of these new technologies in forensic medicine is still in its early phases. However, the possibilities are immense because traditional techniques of examination and opinion formulation in forensic medicine have limitations; therefore, the future will reveal what is applicable in daily practice. AI and machine learning will enhance the precision and efficiency of work in forensic medicine. It can automate a few activities while improving the quality of evidence. The disadvantages of using AI and machine learning may include prejudice, transparency, accountability, ethics, and so on. This technology should be used to supplement, not replace, forensic professionals.

Keywords: Forensics, artificial intelligence, machine learning, ethics

Introduction

In the middle of the twentieth century, British mathematician Alan Turing pioneered work on artificial intelligence (AI), and is now regarded as the founder of AI. Over time, this technology has resulted in the fourth industrial revolution, which is already invading the everyday lives of ordinary people (1). All of this is happening not because AI is superior or intelligent, but because humans are inventive, innovative and curious, as well as more comfortable and hesitant to look at the future critically.

To gain a better grasp of Artificial Intelligence, we will define the differences between AI, machine learning, and data science. Artificial intelligence is the overarching domain, encompassing a wide range of methods and approaches designed to create intelligent machines capable of performing tasks that typically require human intelligence, such as visual perception, speech recognition, and natural language processing. Machine learning and deep learning are subsets of artificial intelligence (2). Deep learning has notable applications in image identification, audio recognition, and natural language processing. Machine Learning focuses on creating algorithms and statistical models that allow computers to learn from data without explicit programming.

Machine learning processes can be supervised, semi-supervised, or unsupervised, depending on whether the data is labelled, unlabelled, or a combination of the two. Machine learning has applications such as recommendation systems, fraud detection, and predictive modelling. Data Science, on the contrary, uses statistical and computational approaches to extract insights and knowledge from data, drawing on all of these domains. This branch has applications in a variety of industries, including healthcare, finance, social media, and e-commerce.

Several surveys have found that people's attitudes towards AI and machine learning are split, with about half of them fearing it. The other half, on the other hand, eagerly welcomes it into their daily lives (3). The fears that AI and machine learning instil in the general public are primarily related to potential job loss, loss of privacy and security, the possibility of misperceptions, a lack of transparency, a lack of understanding of functions, a lack of warmth and understanding that human contact provides, and a slew of ethical issues that its application raises in everyday life (4).

Artificial intelligence and machine learning have long been employed in numerous disciplines of medical science, but they have yet to find a wider and more practical application in forensic medicine. This paper intends to illustrate the present potential for using the same in modern forensic medicine. For this objective, relevant academic literature was searched using the keywords Artificial Intelligence, Machine Learning, Forensic Medicine. This review paper evaluated and used papers that satisfied the specified criteria, which are given in the reference list.

Application Of Ai & Machine Learning In Forensic Medicine

Forensic medicine is a field of medicine that integrates medicine and law. It entails the use of medical knowledge, skills, and competencies for judicial and legal objectives, which may include criminal or civil cases. To name a few applications, forensic medicine is concerned with investigating deaths (forensic thanatology), determining the cause of injury or death, examining evidence, examining living people (e.g., in cases of sexual offences), preparing wound reports, estimating age, and estimating physical and mental status of people in legal matters.

Given that AI and machine learning have long been utilised in health and law, it is fair to expect their application in forensic medicine (5,6), where they can be employed in a variety of ways.

1) **Autopsy analysis**: AI and machine learning algorithms can evaluate medical images to identify injuries, diseases, post-mortem intervals, and causes of death (7-9).

2) **Age and sex estimation:** AI can help estimate the age and gender of victims and offenders bought to the department of forensic medicine and dentistry (10,11).

3) **Facial recognition:** AI and machine learning algorithms can analyse crime scene facial traits and compare them to agency master data. 4) DNA analysis and "omics" data mining: The suffix "omics" refers to numerous disciplines of research, including genomics and proteomics. AI and machine learning can be used to improve the analysis of this data (12-14).

5) **Forensic toxicology**: AI can examine samples more precisely than traditional methods, and can be integrated with robotics to estimate certain parts of testing (15).

6) AI and machine learning can automate **fingerprint analysis** and match crime scene fingerprints with existing databases (16).

Application Of Ai & Machine Learning In Forensic Dentistry

Forensic dentistry, like forensic medicine, is rapidly incorporating AI and machine learning. Although this is mostly a practical application with a specific focus, there are instances where AI has become nearly ubiquitous in the work of forensic dentists. Deep neural networks, artificial neural networks, and computer technology are examples of artificial intelligence and machine learning-based technologies utilised in forensic dentistry (17). These technologies can be utilised in a number of ways to improve forensic dentistry, including:

1) AI and Machine Learning can help forensic dentists analyse dental pictures like radiographs to identify and match persons based on their teeth and jaws (18-20).

2) AI and machine learning can analyse dental photos to assist forensic dentists in estimating age and

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gender of individuals brought to the forensic medicine section from court (21-23).

3) **AI for facial reconstruction**: Create 3-D models of teeth and jaws for advanced decomposition or severe injuries (24).

4) AI and Machine Learning can assess and match bite marks used as evidence in criminal trials (21).

5) **Dental database**: AI and machine learning can search and compare dental data in a master database, identifying individuals.

6) AI and machine learning can automate operations like dental imaging processing, decreasing manual labour and improving investigative accuracy (25).

AI and machine learning technologies are still in their early phases in forensic dentistry, and their utility is dependent on the specific case and inquiry. As a result, it is critical to implement necessary rules and control measures to guarantee that practices are safe, effective, and ethical.

Application Of Ai & Machine Learning In Age Estimation

Age estimation is one of the most significant and common techniques in forensic medicine and dentistry. The selection of an appropriate process for the same is multifactorial, involving the material or sample accessible for analysis, the time and facilities for the procedure, and, most importantly, the experience of the forensic expert. There is no perfect or universal approach for age estimation that can be used on all samples or in all scenarios.

Estimating a person's age is critical in determining his or her biological profile. It becomes more important in criminal investigations and natural disaster scenarios since skeletal remains are sometimes fractured and difficult to identify (26). To effectively assess age, anthropological and biological approaches must be applied. For subadults, age is estimated using forensic anthropology and dentistry approaches based on changes in teeth and bones induced by growth and development. Adult age assessment, on the other hand, is less accurate than that of subadults because it is mostly based on degenerative changes in bones and teeth. Due to the decrease in accuracy with age, alternative approaches have been developed to assess adult age by studying biochemical changes caused by the physiological ageing process. While these procedures are accurate, they also have limits. Thus, combining anthropological and biological methodologies can produce more precise results (27).

An ideal age estimation method should possess the following characteristics: accuracy, dependability, non-invasiveness, acceptability, ease of use, inclusivity, acceptability, privacy, cost-effectiveness, and speed.

Accuracy - In statistics, accuracy refers to the degree to which a measured or observed value is similar to the real or accepted value. It is a measure of how accurately the acquired data represents

Reliability: In statistics refers to the consistency or stability of a measure or test throughout time and under various conditions. Results should be constant independent of conditions or individual, and they should not differ dramatically from one measurement to the next.

Non-invasiveness - The approach should be non-invasive, which means that no one should be exposed to dangerous substances or have a body sample collected.

Easy to use - The approach should be simple to apply, needing minimal training, money, and no special equipment.

Comprehensiveness - The extent to which a parameter encompasses all relevant characteristics or factors in a given context. The approach should be capable of estimating the ages of people from a variety of age groups, races, and ethnicities.

Acceptability - the method should be culturally and socially acceptable to individuals, and it should not discriminate against any certain group.

Privacy - It should safeguard all individuals' personal privacy and not include any personal information other than their age.

It should be cost effective and not demand a significant financial investment.

Speed - the approach should generate results in a reasonable amount of time, avoiding unnecessary delay or annoyance to the individual.

Forensic medicine professionals typically use X-rays of the pubic symphysis, sternal rib end, auricular surface of the ilium, teeth, and cranial sutures to

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estimate age in adults (28). Aside from that, various forensic dental traits are utilised to estimate age, such as tooth wear and tear, the absence or presence of wisdom teeth, the fusion of cranio-palatal sutures, the degeneration status of the jaw bones, the radiographic appearance of tooth roots, the transparency of tooth roots, and so on.

Artificial intelligence and machine learning can be used to estimate a person's age by analysing facial photos, teeth, and long bones. These algorithms may be trained to recognise patterns and traits associated with various ages and then use this information to estimate a subject's age. In dental age assessment, AI can be used to analyse dental x-ray films and compare them based on tooth development and wear and tear (29-30). Taking all of these features into consideration, AI and machine learning together can construct predictive models to determine the Individuals' age using several data sources.

Kluck et al. employed artificial intelligence (AI) to estimate age from hand and wrist skeleton scans. They determined that the findings of their AI-based method outperformed the results of manual skeletal age assessment using the Greulich and Pyle method (31). Shen et al. evaluated Cameriere's approach for measuring tooth age on a sample of around 750 participants. They concluded that using machine learning approaches based on Cameriere's maturation phases improved tooth age determination accuracy over Cameriere's formula. The study results show that machine learning algorithms may be superior to the Cameriere's formula (32).

It is critical to recognise that age estimation is a complex process, and no single method can produce a precise age. To acquire the most accurate age estimation, a variety of methods, including AI and machine learning, should be applied. AI can be used to automate certain operations, such as imaging and patient data analysis, lowering the need for manual labour while enhancing process speed and reliability.

Application Of Ai & Machine Learning In Sex Determination

Sex determination is a crucial component of forensic medicine and is done in a variety of circumstances, such as investigations into crimes, when determining the sex of a victim or the accused can help with identification; in the identification of mass disasters; in missing person cases, when establishing the sex of the remains can help with identification and provide closure for families; in genealogical research, the determination of gender can help confirm family relationships and est. In forensic medicine, sex determination must be done with extraordinary care and accuracy to ensure the results are accurate and free from bias.

In addition, additional parameters may be used - **Skeletal structure**: Examination of bones, such as the pelvis, can reveal a person's sex. **Cranial structures**: measures of the forehead, jawline, and brow ridge can be useful. The difference in tooth size, form, and eruption can be utilised to determine sex. **DNA analysis** is an accurate means of determining an individual's sex, which includes Y-chromosome analysis. The accuracy of sex determination varies according to the method utilised and the subject's developmental stage. To improve the accuracy of the results, it is always best to combine different procedures.

Oura et al.'s work on deep learning in sex estimation from knee radiographs yielded the best overall testing accuracy (90.3%) (33). AI and artificial neural networks can be used to study dental pictures, such as x-rays, and establish a person's gender based on the size, shape, and growth of their teeth and jaws. Bianchi et al. created a semi-automatic approach for predicting sex using the form of the crowns of upper posterior teeth (34).

Sex determination is a difficult technique that relies mostly on dental material. Other methods, such as skeletal sexing, facial sexing, and predictive models, should be utilised to improve result reliability and accuracy. AI and machine learning-based sex determination is a still-developing technology, and its accuracy varies depending on the unique situation and the quality of data used to train it.

Application Of Ai & Machine Learning In Dental Identification

Because each person's teeth are unique, identifying them is critical for dental and personal identity (34). Teeth are not only unique in size and shape, but also have a distinct pattern of grooves and ridges that aid in identification (35). In forensic medicine, dental identification can be used to identify human remains when other methods of identification are unavailable,

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such as in mass disasters or when the body has been degraded or mutilated. Dental identification is comparing dental information, such as radiographs, dental charts, and dental models, to the body's teeth to see if they match. Dental identification is regarded as one of the most reliable methods of identification since teeth are frequently well retained even after fire, trauma, or other damaging factors. As a result, tooth identification is an important aspect of identification and plays a critical role in forensic sciences, providing evidence that can help solve crimes and assist families in missing person instances.

There are various methods in which artificial intelligence might help in tooth recognition. **Individual tooth identification on x-rays**: Artificial intelligence can accurately and reliably identify distinct tooth kinds on radiographs. In addition, AI is increasingly being used to identify the types of dental implants on radiographs. **Dental database**: Artificial intelligence and machine learning can be used to search and match dental records in a dental database, allowing individuals to be identified. **Automation**: Because of the great speed and accuracy of AI and machine learning, it may be utilised to automate some operations and minimise manual labour, resulting in higher accuracy (36). **Predictive analysis and age estimation**: AI and machine learning can assist in forecasting the possibility of specific dental disorders and diseases. Based on patient data, it contributes to the early identification, control, and prevention of specific diseases. **Age estimation**: Artificial intelligence can be used to examine dental pictures to assist forensic professionals in estimating the age of a subject, which is useful when the person's identification is unknown. **Facial reconstruction**: Artificial intelligence can be used to generate 3-D representations of teeth and jaws, assisting in the reconstruction of the face of unidentified remains.

Application Of Ai & Machine Learning In Detection Of Bite Perpetrators

The primary focus of bite mark analysis is the examination of bite marks at the scene of a crime or on any evidence found there. The primary goal of this investigation is to ascertain whether a specific person created the bite mark and to give evidence that can be presented in court (37). The analysis for this technique includes taking and conserving the bite mark, evaluating and documenting the mark, comparing the mark to known dental impressions/records, and deciphering the markings and forming results.

AI and machine learning can help with bite mark analysis in a variety of ways (38,39). **Image enhancement and matching**: Using AI and machine learning, enlarged models of bite marks may be created, making it easier for investigators to study them and determine the pattern and any special features that may exist. **Automation**: AI may automate specific operations, such as processing dental photos, saving time and increasing result accuracy while lowering the potential of human error and the requirement for manual effort. **Age estimation**: Artificial intelligence (AI) can be used to analyse dental photos to assist forensic professionals in estimating the age of individuals based on bite marks, which can be useful in circumstances when the individual's identity remains unknown.

Conclusions:

The application of artificial intelligence and machine learning in forensic medicine is presently in its early phases. Nevertheless, the options are many, and the future will reveal what is applicable in everyday practice. Using AI and Machine Learning provides various advantages over older methods:

1) **Greater precision and efficiency**: Modern techniques enable forensic professionals to evaluate vast amounts of data, such as imaging and patient records, to identify and match persons faster and more correctly.

2) AI and machine learning can **automate operations** like image and data processing, reducing the need for manual labour while increasing speed and accuracy.

3) **Improving evidence quality**: These techniques can be used to improve and enhance photographs in order to more accurately analyse variances in samples received, ultimately improving the credibility of evidence in court.

Furthermore, as previously stated, AI and machine learning can be used to evaluate dental and skeletal images to aid forensic experts in determining the age of individuals in unidentified cases; with the help of

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these methods, 3-D reconstruction of the face with teeth and jaws may be accomplished, helping in determining the identity of unknown cases; AI can be used to examine and align with bite marks, which can be used as testimony in legal cases; AI and machine learning can be used in searching and matching dental records in database, which can help identify individuals.

On the contrary, there are several drawbacks to using artificial intelligence, such as discrimination, transparency, accountability, privacy, security ethics, and so on.

a) **Bias and prejudice**: These systems can reinforce bias and discrimination in the data on which they were trained. As a consequence, persons' ages and genders may be misidentified or mis-estimated.

b) **Limitations of transparency and accountability:** AI systems' decision-making processes remain unclear, rendering it impossible to explain and hold them answerable. As a result, they are difficult to present as testimony in court.

c) **Privacy and security problems**: AI and machine learning rely heavily on patient data, which can raise privacy and security concerns, especially with the widespread use of electronic dentistry records.

d) **Overreliance on technology**: Forensic specialists may become overly reliant on AI, perhaps hindering their ability to complete tasks independently.

e) **Limited context understanding**: the aforementioned systems may require assistance from forensic professionals to comprehend the complexities of human health and disease, particularly in legal contexts.

f) **Job displacement**: Automation of specific duties is expected to reduce job displacement and unemployment as AI and machine learning become more widely used.

g) **Ethical problems**: The application of AI in forensic medicine raises ethical concerns about autonomy and healthcare decision-making. As the usage of these technologies' spreads, ethical concerns will become increasingly important.

When developing and using AI and machine learning in forensic medicine, it is critical to evaluate these potential benefits and drawbacks, as well as have regulations and safeguards in place to avoid potential bad consequences. It is also critical to ensure that Artificial Intelligence technologies are utilized as a supplement rather than an alternative for forensic professionals.

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