



The scope of Artificial Intelligence in Human Identification through Forensic Odontology

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ABSTRACT-

This article explores the application of artificial intelligence (AI) in forensic odontology, specifically in age estimation, identification, and sex determination. The history and development of AI in various fields are discussed, highlighting its potential to automate tasks and overcome human limitations. The importance of forensic odontology in human identification, especially in cases of mass disasters and decomposed remains, is emphasized. The article reviews several studies that have used AI models (Machine Learning and Deep Learning) such as Support Vector Machines (SVMs), artificial neural networks (ANN), convolutional neural networks (CNN), for dental analysis and identification. The methodologies, materials, and results of these studies are presented, showcasing the accuracy and effectiveness of AI in age estimation and sex determination. The limitations and challenges of AI technology in forensic odontology are also acknowledged. The article concludes by emphasizing the significance of accurate forensic analysis and the potential of AI to enhance these processes. It suggests further research opportunities to improve the accuracy and reliability of AI-based methods in forensic odontology.

Keywords: Artificial intelligence, artificial neural networks (ANN), convolutional neural networks (CNN), and deep learning, forensic odontology

Introduction

The concept of artificial intelligence (AI) can be traced back to the workshop conducted in 1965 at the campus of Dartmouth College, wherein, McCarthy convinced the attendees to accept the perception of AI.¹ He defined AI then as “the science and engineering of making intelligent machines”¹

It is said to be the beginning of the first “Golden age” of AI.² From 1965 till 2019 many researchers have given different definitions for AI, an Indian researcher Rai et al. (2019) has defined artificial intelligence “as the ability of a machine to perform cognitive functions that we associate with human minds, such as perceiving, reasoning, learning, interacting with the environment, problem-solving, decision-making, and even demonstrating creativity.”³

The field of AI has shown an upsurge in the 21st century with Machine Learning applications (from 2000-2015) and the impressive successes of Deep Learning in the last decade. Advancement in AI has not only helped in the development of human society in our time but also there has been a historic revolution shaped in both theories and techniques.³ Since 1980, AI has been applied to numerous topics to name “computer vision, natural language processing, the science of cognition and reasoning, robotics, game theory, and

machine learning”.⁴

According to Jain et al., “three revolutions in AI research over the years are the result of (1) the introduction of a much more sophisticated class of algorithms; (2) the arrival on the market of low-cost graphics processors capable of performing large amounts of calculations in a few milliseconds; and (3) the availability of very large, correctly annotated databases allowing for more sophisticated learning of intelligent systems”.⁵

The aim of AI has been described in the literature by T. J. M. Bench-Capon “as to spread and enhance the capacity and

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proficiency of mankind in tasks of reshaping nature and leading the society through intelligent machines with the intention of comprehending a society where humans and machines live harmoniously together".⁶

AI, if trained properly, can automate tasks, and can overcome human limitations in the execution of complex tasks (like, processing massive datasets to derive important information).⁷ In recent times AI has been used tremendously in medical sciences and forensic sciences, posing new challenges. There are both advantages and disadvantages to using AI methodologies to solve forensic problems. Over time, AI technology has made an effort to get over the human subjectivity and bias constraints of the conventional forensic sciences approach, decrease human subjectivity and errors, and provide a stronger scientific foundation that could favor the acceptance of expert evidence.⁷ Moreover, by utilizing computational approaches, human cognitive talents can open up a number of opportunities for offering useful tools that emphasize the scientific process, improve the forensic expert's professional competence, and offer a different perspective on a case.⁸

Forensic odontologist deals both with living and deceased subjects. In the scenario of mass disasters forensic odontologists help in the identification of the deceased with dental remains as sometimes identification done alone based on visual identification shows a higher error. Matching is done based on dental records of the missing person (antemortem data) with post-mortem data (PM) using INTERPOL DVI forms. The field of forensic dentistry is crucial for determining the age and gender of disaster victims as well as for aiding in victim identification. Forensic odontologists assist in determining the chronological age of a living person in cases involving migrants, child laborers, and athletes applying for admittance.⁹

In recent years, forensic odontology has used AI as a technological innovation, and in this review, studies that have used AI-based models to identify a person using dental records, radiographs, and dental casts have been examined. The research papers examined here have made use of AI models that were primarily created and built to combat the unpredictability brought on by the human eye and intellect. AI's area of machine learning is deep learning (DL), which is a subclass of machine learning (ML).

Materials and methods

The research paper under consideration was located by

looking for items that had been published in the literature over the previous ten years in a number of well-known search engines, including PubMed, Medline, Embase, Cochrane, Google Scholar, Scopus, and Web of Science. The search was narrowed to papers about applications of AI, AI applications in forensic sciences, and AI applications in forensic odontology. The amalgamation of keywords like artificial intelligence, forensic sciences, forensic odontology, forensic dentistry, deep learning, machine learning, artificial neural networks, and convolutional neural networks, was used for data searching.

The inclusion criteria for selecting articles in this review encompassed several key factors. Firstly, the articles had to be focused on the field of forensic odontology, encompassing studies specifically related to dental analysis in forensic investigations. Additionally, articles based on forensic medicine and forensic sciences were also considered to provide a broader perspective. A crucial requirement was the detailed explanation of the AI technology used in the study model, ensuring a clear understanding of the AI methodologies employed. Furthermore, the inclusion criteria emphasized the importance of discussing measurable or predictive outcomes in a well-documented manner, allowing for the evaluation of the effectiveness of the AI models. The material and methods section of the articles needed to disclose the data sets utilized for training, validating, or evaluating the AI model.

Conversely, the exclusion criteria aimed to refine the selection process. Articles consisting solely of abstracts without full-text access were excluded to ensure comprehensive analysis and access to complete information. Moreover, research articles published in languages other than English were excluded to maintain consistency and facilitate understanding across the review. By adhering to these inclusion and exclusion criteria, the selection process ensured the inclusion of relevant and comprehensive studies in the review of AI applications in forensic odontology.

Discussion:

In circumstances where the body is totally mutilated and disfigured because of ferocious crime, severe accidents including road traffic accidents or occupational accidents, or due to mass disaster of any kind (air crash, war, fire, navy disaster, man-made disaster, natural disasters, terrorist



attacks, tsunami, floods) in such situations body is totally unrecognizable and identification of deceased becomes very important.

Role of AI in Age Estimation

Fan et al. collected 15369 OPGs for creating an AI model for identification purposes from 6300 persons, wherein each participant of the study had 2 OPGs that were used as AM & PM data for training CNN. From the same pool of data, the “test set” was considered for evaluation purposes of the network. Results demonstrated 97.7% accuracy and excellent efficacy, matching nearly all of the photos. The drawback of this research study was that the AI model was not trained to evaluate mixed dentition, which still required manual assessment.¹⁰

Tobel et al. performed age estimation by staging the development of lower third molars using a modified Demirjian’s approach that used DCNNs. Three forensic odontologists reviewed 400 OPGs that were part of the study material. According to the findings, 51% of the stages were generally properly identified. The authors came to the conclusion that these AI-based approaches for age estimate exhibit promising experimental results, but they still require more validation for possible forensic applications in the real world.¹¹

Balan H et al. developed a classification model using Demirjian’s method for estimating dental age in the population of children in south India. A total of 100 sample photos were used in the evaluation, 60 of which were used as training data and 40 as testing data. The researchers employed fuzzy neural networks with teaching learning-based optimization (FNN-TLBO) for this study. Their findings revealed that the proposed model outperformed Demirjian and other algorithms they looked into, including MELM-SRC, RBFN, and ANFIS, with a high prediction accuracy rate of 89%. In order to identify new maturity scores and logistic curves, researchers suggested that sample sizes for all age ranges should be raised in the future.¹²

For age estimation from 13 to 25 years, Magnetic resonance imaging (MRI)-based multi-factorial methodology was proposed by Stern et al. They used a DCNN architecture for age prediction to estimate the age of 322 patients by evaluating their hands, clavicles, and lower third molars. When measured by mean absolute regression error of 1.01 0.74 years, the approach demonstrated outstanding age regression performance.¹³

Back et al. trained a Bayesian convolutional neural network

(BCNN) to do an age estimate, getting a coefficient of correlation of 0.91 by analyzing 12,000 OPGs of the upper and lower jaws. Initial findings indicated that the model was motivating but cautioned that the accuracy was not yet sufficient for usage in ordinary applications.¹⁴

Vila-Blanco et al. two CNNs (DANet and DASNet) were trained using 2000 OPGs ranging in age from 4.5 to 89. In this study, the researcher looked at each photograph to see if the dentition appeared to match the estimated chronological age. The two tested CNNs’ estimated ages and the actual ages showed a strong correlation, with testified coefficients of correlation of 0.87 and 0.90, respectively.¹⁵

Banar N et al. employed 400 OPGs to train CNNs to create an AI model that automates the staging process by utilizing deep learning to its fullest extent. Twenty OPGs were examined by three forensic odontologists, one for each gender and developmental stage. It was suggested to follow a three-step process, and five times cross-validation was used to verify the outcomes. To address the problems, pre-trained CNNs, data augmentation, and transfer learning were considered.¹⁶

Merdietio B R, approximated age by using an automated developmental stage allocation system to look at the third molar in 400 OPGs. Lower left third molars were staged using an AlexNet Deep CNN method after being manually marked with bounding boxes. Three methods of tooth segmentation—bounding box (BB), rough (RS), and complete (FS)—were used for processing and segmentation. According to the authors, automating stage allocation can perform better if only the third molar is segmented. The stage allocation accuracy for FS was 0.61, and it outperformed BB in terms of the percentage of correctly allocated stages.¹⁷

Role of AI in Gender Determination from skull and jaw bones

Gender determination from skull bone analysis has been reported to show 90% accuracy.⁹ Guatelli et al. have demonstrated in their research that gender differences in permanent dentitions are caused by hormonal changes that have an impact on tooth size and form.¹⁸

The victim’s jaw size and shape can reveal information about the victim’s gender. Additionally, the masticatory pressures that differ between males and females affect the form of the mandible. Gender determination in forensic odontology has been done over the years using radiographs



of jawbones as not only they are simple, and economical but also is a less destructive method that is applicable for living and deceased individuals.⁹ Recently researchers have started exploring artificial intelligence technology for sex determination in forensic odontology.

Fidya et al. (2018) described an AI-based model for gender determination by sexual dimorphism in canines. They studied decision trees, multi-layer perceptron (MLP) methods, and ANNs Naive Bayes, for studying sexual dimorphism in canines. Images for training used were 100 and 50 images for validating in testing. Teeth measurements of both upper and lower canine were done; their results showed an accuracy of MLP method 84% and an absolute error value lower than other tested methods. They recommended the proposed method for sex determination from canines.¹⁹

James Bewes (2019) trained neural networks for sex determination from 900 CT images between 18 and 60 years of age of skull. The methodology they worked on was already in place called "GoogLeNet." This is a trained model on "1.2 million images of 1000 different common everyday objects" So the concept researcher applied was of "transfer learning" in artificial intelligence which means "when a pre-existing neural network is modified for a new task". Therefore, they modified GoogleNet neural network within MATLAB, to classify input images as "male" or "female." Their results showed 95% accuracy for sex determination using the modified technique. Further researchers concluded with the fact that artificial intelligence models once trained can be easily implemented and are not only faster to use but also give ease to potentially eliminate human bias in sex determination.²⁰

Yang et al. (2019) presented a more effective BPNN method for determining the gender of the skull. A total of 267 skulls—153 female and 114 male—had their six predetermined features quantified using computer-aided measuring and used as network inputs. The testing stage's accuracy percentage was 96.764%, according to the results. Researchers found that their suggested method outperformed conventional approaches in terms of classification accuracy, learning capacity, and convergence speed.²¹

Patil et al. (2020) studied six morphometric parameters on 509 OPGs from the age range 18-70 years to evaluate ANNs reliability for gender determination as compared to other statistical techniques and discriminant analysis. They found

that the ANN gave better results in comparison compared to the alternative methods, 75% of samples were correctly categorized. The researchers concluded that it's important that the technique has to be validated on a larger population, considering more variables like different social, environmental conditions and dental diseases.²²

Esmailyfard et al. (2021) used classification algorithms, such as Random Forest and Support Vector Machine classifier, to determine gender preference. 9 dental characteristics were examined between the ages of 15 and 25 on 450 Cone Beam Computed Tomography (CBCT) images of lower first permanent molar teeth. Lower first molar teeth might be employed for sex determination using the proposed AI models, according to the study's findings, which indicated computational models could categorize the photos with an average accuracy of 92.3%.²³

It is important to strike a balance between leveraging the advantages of AI in forensic odontology while acknowledging its limitations and ensuring human oversight and ethical considerations are in place for reliable and responsible use.

Conclusions

The article asserts that forensic odontology investigations can greatly benefit from the implementation of artificial intelligence techniques. It emphasizes the significance of precise age estimation and sex determination in forensics, highlighting the role of artificial intelligence in achieving this. Additional research efforts could concentrate on enhancing the accuracy, efficiency, and dependability of age estimation and sex determination methods through the application of AI.

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