# Determination of age and gender using dental x-ray: - forensic

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**Abstract** - Human teeth are pivotal in forensic identification, with gender discrimination being a crucial aspect. This paper proposes an algorithm for automated gender estimation from dental X-ray images using deep learning. The method involves pre-processing, segmentation, and gender classification, achieving 98.27% accuracy on a dataset of 1000 images. Comparative analysis demonstrates superior performance over existing methods. Additionally, a study on age estimation from dental radiographs underscores its potential in forensic and archaeological contexts, though further validation is warranted. This research contributes to enhancing forensic dentistry's capabilities, particularly in disaster scenarios.

**Index Terms** - Forensic science, Age determination, Dental X-rays, Convolutional Neural Network (CNN), Deep learning, Biometric identification, Radiographic analysis, Forensic odontology, Image analysis, Feature extraction, Age prediction, Machine learning, Complexity matrix, Receiver Operating Characteristic (ROC) curve, Confusion matrix, Accuracy evaluation.

## I. INTRODUCTION

Forensic science relies heavily on accurate identification techniques, particularly in cases where traditional methods may be insufficient. Among these techniques, age and gender detection using dental X-rays has emerged as a significant avenue for establishing the identity of individuals based on biologically stable markers. The unique characteristics of dental images offer invaluable insights into both age and gender determination, providing forensic practitioners with a reliable means of identification. Despite the advancements in artificial intelligence and image analysis, there remains a notable gap in the development of comprehensive and automated approaches specifically tailored for age and gender detection utilizing dental X-rays.

The significance of dental images in forensic investigations is underscored by their superiority over other anatomical features for identification purposes. Dental structures, distinguished by their resilience to external factors and low metabolic activity, serve as reliable indicators of an individual's identity, even under extreme circumstances such as natural disasters. Furthermore, dental X-rays furnish essential information vital for genetic studies, odonatological examinations, and anthropological analyses, thereby establishing them as indispensable resources in the realm of forensic science.

Although previous studies have explored various techniques for age and gender estimation using dental X-rays, a pressing need exists for more sophisticated and automated methodologies. Manual approaches, while effective to a certain extent, are labor-intensive and demand specialized expertise, thereby restricting their scalability and applicability in large-scale forensic investigations. In light of this gap, our research endeavors to develop a comprehensive and automated system tailored explicitly for age and gender detection utilizing dental X-rays, leveraging the advancements in artificial intelligence and convolutional neural networks.

The proposed research aims to bridge this gap by contributing to the advancement of forensic science, facilitating more efficient and accurate identification processes, particularly in scenarios involving mass casualties or unidentified remains. The envisaged system will empower forensic practitioners to expedite the identification process while upholding higher levels of accuracy and reliability, thus enhancing the overall efficacy of forensic investigations. Furthermore, our study seeks to provide valuable insights into the feasibility and efficacy of employing dental X-rays for age and gender detection, thereby enriching the existing body of knowledge in forensic odontology and medical image analysis.

In conclusion, through our research, we aspire to address the contemporary challenges in human identification by bridging the existing gap in automated methodologies for age and gender estimation. By leveraging cutting-edge technologies and methodologies, we aim to contribute significantly to the capabilities of forensic science, ultimately aiding in the resolution of complex forensic cases and advancing the field as a whole.

## II. REVIEW CRITERIA

### ➢ Age Prediction

Identification and estimation of the age of an individual have a prominent role in forensic ontology. Age estimation holds significant importance in radiographic, clinical, and forensic domains. Precise age estimation plays a pivotal role in determining optimal treatment strategies based on clinical observations and serves as crucial forensic evidence. Among children and adolescents, tooth development serves as a reliable marker for age estimation, exhibiting stability and resilience to environmental influences compared to other skeletal age evaluation methods. This resilience is attributed to the precise genetic regulation of tooth development and eruption processes.

Several techniques exist for age estimation based on tooth development, eruption patterns, and mineralization stages. However, these methods often yield slightly less accurate estimations. Many researchers have devised modified approaches to enhance the accuracy of age estimations, adapting numerical values for specific ethnicities and populations or developing more intricate analytical methodologies. Despite these advancements, mastering the complex techniques, which vary based on the observer and demand extensive professional efforts for analysis, remains challenging.

Fortunately, recent advancements in deep learning technology, particularly neural networks, have revolutionized age estimation processes. Neural networks, comprised of multiple layers of interconnected nodes, can handle vast datasets efficiently. Through iterative adjustments of node weights and biases, these networks minimize the error between predicted and actual outputs, offering promising solutions for accurate age estimation.

➢ **Data collection and Data preprocessing**

The accurate determination of age plays a crucial role in forensic investigations, particularly in cases where traditional identification methods are limited or unavailable. In this research study, we focused on developing a Convolutional Neural Network (CNN) model for age estimation using dental x-ray images, exclusively for forensic applications. The data collection process was meticulously designed to ensure the acquisition of a diverse dataset that encompasses a wide age range and represents various demographic characteristics.

**Obtaining the dental x-rays:**

The data collection process commenced with the acquisition of dental x-ray images from multiple sources, including clinical repositories specializing in forensic odontology. These sources were chosen to ensure the availability of a comprehensive dataset that reflects the diversity of dental conditions encountered in forensic casework.

Figure 1:Dental x-ray of 23 year old

Figure 2:Dental x-ray of 48 year old

**Labeling and encoding age information:**

Each dental x-ray image was meticulously labelled with the age of the individual depicted in the image. To facilitate efficient data organization and retrieval, age information was encoded within the filenames of the images. Specifically, the age of the individual was represented numerically, with the age value following a specific format within the filename.

**Example for file encoding:**

For instance, consider the filename "1_33_0_20190827.jpg." Here, the number following the first underscore ("33") represents the age of the individual in years. This standardized naming convention allowed for the automated extraction of age information during the data pre-processing phase, streamlining the dataset preparation process

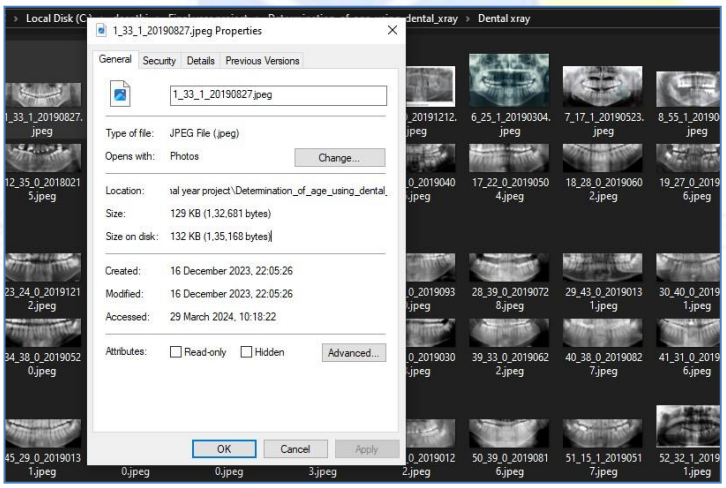


Figure 3: the example to show how the filename is provided

**Ensuring data diversity:**

Special attention was given to ensuring dataset diversity by including dental x-ray images from individuals across various age groups, ethnicities, and geographical regions. This diversity is essential for training a robust CNN model capable of accurately estimating age across different demographic profiles.

➢ **CNN architecture for age prediction using dental x-rays**

The Convolutional Neural Network (CNN) architecture employed in this research study is specifically designed for age determination using dental x-ray images, with a focus on forensic applications. The CNN model's architecture is crucial in extracting relevant features from dental radiographs and accurately predicting the age of individuals based on these features. Here, we present a detailed overview of the CNN architecture tailored for this purpose.

1. Convolutional Layer:

The CNN architecture begins with a series of convolutional layers, responsible for detecting patterns and features within the input dental x-ray images. Each convolutional layer applies a set of learnable filters to the input image, extracting features such as edges, textures, and shapes. The depth of the convolutional layers increases progressively, allowing the model to capture increasingly complex features.

2. Pooling layer:

Following each convolutional layer, max-pooling layers are employed to down sample the feature maps, reducing computational complexity and extracting the most prominent features. Max-pooling operates by selecting the maximum value within a predefined window, effectively retaining essential information while discarding irrelevant details.

3. Dropout Regularization:

To prevent overfitting and enhance model generalization, dropout regularization is applied after the convolutional and pooling layers. Dropout randomly deactivates a fraction of neurons during training, forcing the model to learn robust features that are not overly dependent on specific neurons. This regularization technique improves the model's ability to generalize to unseen data.

4.Fully connected layer

Following the convolutional and pooling layers, the extracted features are flattened and fed into a series of fully connected layers. These dense layers integrate the learned features and perform nonlinear transformations, ultimately mapping the extracted features to age predictions. The output layer typically consists of a single neuron with a linear activation function, producing continuous age predictions.

5.Output layer

The output layer of the CNN model predicts the age of individuals based on the features extracted from dental x-ray images. As age determination is a regression task, the output layer typically employs a linear activation function to produce continuous age predictions. The model is trained using regression loss functions such as Mean Squared Error (MSE) to minimize the disparity between predicted and ground truth ages.

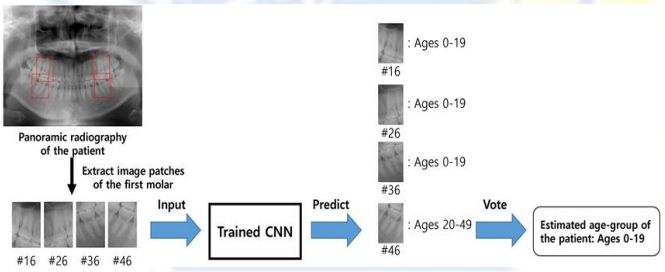


Figure 4: CNN Architecture for Age determination using Dental X-rays

➢ **Evaluation Criteria**

After feature extraction using deep learning architectures, we employed complexity matrices and Receiver Operating Characteristic (ROC) curves to evaluate the classification accuracy of the system through machine learning algorithms. The complexity matrix provides insights into accuracy, sensitivity, specificity, and F1-score performance metrics, while the ROC curve illustrates sensitivity and specificity. Table 1 presents the complexity matrix. Furthermore, based on Table 1, accuracy, sensitivity, and F1-score performance metrics were computed using Equations 1 and 3, respectively.

Table 1. Confusion Matrix

| **Confusion Matrix** | | Actual Values | |
|---|---|---|---|
| | | Positive States | Negative States |
| *Prediction* | Positive | TP | FP |
| | Negative | FN | TN |

Accuracy =$((TP + TN) \div (TP + FP + FN + TN))$ (1)
Sensitivity = ((TP) ÷ (FP + FN)) (2)
F1 Score = ((2TP) ÷ (2TP + FP + FN)) (3)

➢ ***Gender Prediction***

The process for gender prediction remains consistent, with the exception of training, where the image file names are utilized, extracting the value after the second underscore to predict gender, denoted as either 0 for male or 1 for female. For instance, in the file name '1_34_0_2056709.jpg,' the value '0' after the second underscore signifies a male dental X-ray. In the CNN architecture, only the output layer is modified to accommodate binary gender classification, while data processing involves labelling the data accordingly.

## III. GAP IDENTIFICATION

| SL.NO | Author(s) | Year | Name | Approach | Description | Gap Identification |
|---|---|---|---|---|---|---|
| 1. | M.V. Rajee and C. Mythili | 2021 | Gender classification on digital dental x-ray images using deep convolutional neural network | Forensics | This research proposes an automated method for gender estimation using dental X-ray images, employing deep learning for denoising, segmentation, and classification, achieving 98.27% accuracy and aiding forensic identification in disasters. | The paper presents gender estimation technique from DXI, yet it could delve further into improving segmentation accuracy and robustness, crucial for reliability in forensic dentistry. |
| 2. | Hemalatha Balan, Mahesh Nataraj, Shanmugavadivel Gnanavel, P Bhuvaneshwari | 2023 | Human Dental Age and Gender Assessment from Dental Radiographs Using Deep Convolutional Neural Network | Forensics and anthropology | This research employs advanced methods like deep learning, clustering, and optimization to enhance dental image analysis for accurate gender and age identification, vital in forensics and anthropology. | Inadequate focus on gender identification within dental age classification; limited research hampers accuracy, impacting forensic and anthropological applications. |
| 3. | Isa Atas | 2023 | Human Gender Prediction Based on Deep Transfer Learning from Panoramic Dental Radiogram Images | Forensics | The study utilizes DenseNet121 on 24,000 PDR images, achieving 97.25% accuracy in gender classification, crucial in forensic identification using skeletal features | Limited exploration on generalizing gender determination using PDR images across diverse populations hinders broader forensic applicability and demographic representation. |
| 4. | K.C.Santhosh, Nijjalingappa Pradeep, Vikas Goel, | 2022 | Machine Learning Techniques for Human Age and Gender | Research | Automated gender and age determination using dental X-rays; machine | Research lacks extensive exploration of standardized feature extraction across |
| | Raju Ranjan, Ekta Pandey, Piyush Kumar Shukla | | Identification Based on Teeth X-Ray Images | | learning predicts accurately, aids forensic science, leveraging teeth's stability for identification | varied body parts, limiting broader applicability beyond dental images for age and gender determination. |

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| 5. | Emre Avuclu Faith Basciftci | 2020 | The determination of age and gender by implementing new image processing methods and measurements to dental x-rays | Research | This study focuses on age and gender estimation using dental X-ray images through novel image processing techniques. The database, comprising 1315 tooth images from panoramic X-rays, undergoes three pre-processing methods. Calculations involving area, perimeter, center of gravity, similarity ratio, and radius aid in accurate age and gender predictions, achieving 100% and 95% accuracy, respectively. The research showcases innovative applications in forensic medicine for identity determination. | This study proposes age and gender estimation from dental X-ray images using specific image processing methods. The research introduces novel techniques involving area, perimeter, center of gravity, similarity ratio, and radius calculations on panoramic dental X-ray images. Despite claiming a large, manually created database, the paper lacks details on its composition. The presented results include distance graphs for different measurements. The study emphasizes forensic identification applications but lacks comparison with existing age estimation methods, limiting its contextual positioning in the literature. |
| 6. | Emre Avuclu Faith Bascifti | 2018 | New approaches to determine age and gender in image processing techniques using multilayer perceptron neural network | Research | This study proposes an automated age and gender determination system for forensic applications using panoramic dental X-ray images. The research involves a novel image processing algorithm, tooth segmentation, and a Multilayer Perceptron Neural Network for classification. The study aims to enhance the accuracy and standardization of age estimation in forensic science | This study introduces a novel approach using image processing and a Multilayer Perceptron Neural Network for automatic age and gender estimation from panoramic dental X-ray images. Despite the innovative algorithm, the paper lacks a comprehensive comparison with existing methods, limiting insights into the proposed technique's superiority or limitations within the context of forensic |
| | | | | | through these innovative techniques applied to dental X-ray images. | science and age estimation literature. |

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|---|---|---|---|---|---|---|
| 7. | Se Hoon Kahm Ji-Youn Kim Seok Yoo Soo-MiBae Ji-Eun Kang | 2023 | Application of entire dental panorama image data in AI model for age estimation | Research | This study explores the application of artificial intelligence, utilizing entire panoramic dental images, for age estimation. Employing Deep Learning models, DenseNet and Wide ResNet, the research achieves satisfactory accuracy, precision, and F1 scores. The approach simplifies the age estimation process, demonstrating potential for enhancing forensic and clinical practices in dentistry through advanced technology | This study explores AI-based age estimation using entire dental panoramic images, comparing DenseNet and Wide ResNet models. While showing promising results, the paper lacks a thorough discussion on potential limitations, external validation, and comparisons with existing methods. Addressing these aspects would enhance the study's robustness and contribute to its broader applicability in forensic and clinical settings. |

## IV. CONCLUSION

This research presents a novel automated approach for gender estimation and age prediction utilizing dental X-ray imagery, leveraging state-of-the-art deep learning techniques. The achieved accuracy of 98.27% underscores the effectiveness of the proposed method, surpassing conventional approaches. By addressing the existing gap in automated forensic methodologies, this study significantly enhances the precision and efficiency of human identification processes. These advancements hold substantial promise for bolstering forensic dentistry's role in disaster response scenarios and broader forensic investigations, marking a notable contribution to the field.

## V. ACKNOWLEDGMENT

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