Estimating chronological age using neural networks: an evaluation of tomographic images of the pulp chamber

Authors and affiliations:
William José Lopes Junior[1], Alexandre Vieira Pereira Pacelli[2], Davi Magalhães Pereira[2], Heder Soares Bernardino[3], Marcelo Bernardes Vieira[3], Saulo Moraes Villela[3], Karina Lopes Devito[4]

[1]Master's student at Dentistry Program, Federal University of Juiz de Fora.
[2]Master's student at Computer Science Program, Federal University of Juiz de Fora.
[3]Professor at the Department of Computer Science, Federal University of Juiz de Fora.
[4]Professor at the School of Dentistry, Federal University of Juiz de Fora.

Abstract:

Age estimation is an important demand in Forensic Dentistry, both to assist in the identification of living individuals (related to migratory movements, lack of documentation, memory loss, child support, underage marriage, legal responsibility, and cases of child pornography) and for the identification of corpses and human remains[1].

A widely known and accepted method for estimating chronological age is the evaluation of the pulp chamber dimension of permanent teeth[2-3]. The pulp chamber is a space inside the tooth crown, where the dental pulp is located, composed of nerves, blood vessels, and connective tissue. The entire chamber is surrounded by dentin, protected by enamel. As age advances, there is a reduction in the volume of the pulp chamber due to the deposition of secondary dentin. This decrease can be observed in imaging exams and is an indicator of chronological age in adult individuals. Despite advances in radiographic exams and image evaluation software, the determination of pulp measurements and, consequently, age estimation, is still significantly influenced by the subjectivity of the image evaluator, as manual boundary marking and measurements may vary. In an attempt to reduce this interference, artificial intelligence models are being used to assist in age estimation[4-7].

Therefore, the present study aimed to develop convolutional neural networks (CNNs) to assist in estimating the age of adult Brazilians by evaluating the pulp area in cone beam computed tomography (CBCT) images of upper central incisor teeth. This study was approved by the Research Ethics Committee involving Human Beings of the Federal University of Juiz de Fora (No. 5,485,995/2022). CBCT images of 554 healthy teeth, belonging to individuals from the Zona da Mata Mineira region (Minas Gerais, Brazil), of both sexes and aged between 18 and 60 years, were analyzed, divided into eight age groups.

For evaluation, the most central coronal and sagittal sections of each tooth were used. These sections were subsequently cropped to reduce surrounding structures around the tooth. In addition to the original images, a “side by side” section was also created, allowing simultaneous evaluation of coronal and sagittal sections (Figure 1). To select the study's regions of interest, "tooth crown" and "pulp chamber" masks were manually created on coronal and sagittal sections of 194 teeth, which helped the neural networks to perform the segmentation process, using a proportion of 70% for network training, 15% for validation, and 15% for testing. For the age group classification network, images (coronal, sagittal, and “side by side”) of the remaining 360 teeth were used, using the same proportion as the segmentation network.

Both for the segmentation process and classification, the YOLOv8-CNN[8] was used, in ExtraLarge and Small variants, for segmentation and classification, respectively. The hyperparameter configuration was the same for both CNNs. The initial learning rate used is 1×10^{-3}, with a batch size of 16 and 160-pixel images. As for the optimizer, the "auto" parameter was used. The models were trained over 1000 epochs, without using pre-trained weights. To avoid overfitting, the Early Stopping in method was employed, with 150 epochs. During training, the following data augmentation techniques were

implemented: modification of the HSV-Value component, translate, scale, and flip left-right. The development of CNNs was conducted through the Kaggle platform, based on the Python language.

The following metrics were calculated to evaluate the performance of the created CNNs: accuracy, precision, recall, F-measure, and mean average precision (MAP).

The average results obtained for the segmentation network were: precision of 0.983, recall of 0.998, and MAP of 0.994. For the classification networks, the following average (standard deviation) accuracies were obtained: 0.32 (0.05), 0.33 (0.04), and 0.34 (0.03), for coronal, sagittal, and "side by side" sections, respectively.

It can be concluded that the CNN can segment images very satisfactorily in their regions of interest, even with a reduced dataset. As for the classification network, although it demonstrates promising results, there is a need for a more robust dataset for the network to detect the subtle changes in images related to age variation.

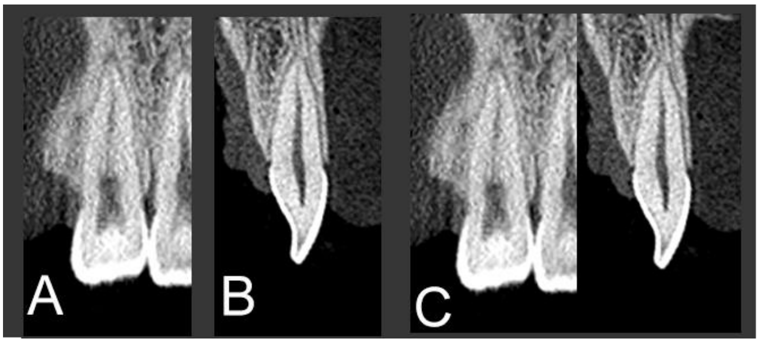

Figure 1 – Coronal (A), sagittal (B) and "side by side" (C) tomographic sections.

References:

1. Molina A et al. Dental age estimation based on pulp chamber/crown volume ratio measured on CBCT images in a Spanish population. Int J Legal Med. 2021 Jan;135(1):359-364. doi: 10.1007/s00414-020-02377-y.
2. Alharbi HS Sr et al. Age estimation by Kvaal's method using digital panoramic radiographs in the Saudi population. Cureus. 2022 Apr 2;14(4):e23768. doi: 10.7759/cureus.23768.
3. Nouaman MN et al. Application of the Kvaal method with cone beam for the determination of a local formula for the age estimation of adult African melanoderma subject, Côte d'Ivoire. J Forensic Odontostomatol. 2022 Apr 30;40(1):2-11.
4. Guo YC et al. Accurate age classification using manual method and deep convolutional neural network based on orthopantomogram images. Int J Legal Med. 2021 Jul;135(4):1589-1597. doi: 10.1007/s00414-021-02542-x.
5. Patil V et al. Age Assessment through root lengths of mandibular second and third permanent molars using machine learning and artificial neural networks. J Imaging. 2023 Feb 1;9(2):33. doi: 10.3390/jimaging9020033.
6. Wang J et al. A population-based study to assess two convolutional neural networks for dental age estimation. BMC Oral Health. 2023 Feb 17;23(1):109. doi: 10.1186/s12903-023-02817-2.
7. Zhou Q et al. Medical image classification using light-weight CNN with spiking cortical model based attention module. IEEE J Biomed Health Inform. 2023 Feb 1;PP. doi: 10.1109/JBHI.2023.3241439. Epub ahead of print.
8. Jocher G et al. Ultralytics YOLOv8. 2023. Available at: https://github.com/ultralytics/ultralytics.