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VALIDATION OF DEEP CONVOLUTIONAL NEURAL NETWORK FOR AGE ESTIMATION IN CHILDREN USING MANDIBULAR PREMOLARS ON DIGITAL PANORAMIC DENTAL IMAGING

NORHASMIRA BINTI MOHAMMAD

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ABSTRACT

The growing number of undocumented or irregular migrants has become a source of concern in recent years, particularly in third world countries. Southeast Asia has been exploited as an irregular migratory route for the last decade, with Malaysia reporting incidences of forced marriages. The chronological age of an individual is one of the critical pieces of evidence required by the authorities when determining the refugee status and sentencing criminals. Estimating the age of the deceased bodies at the forensic scene is also essential in some instances. Traditionally, age estimation is dependent on radiographic examinations, and its application requires human competence. Demirjian's technique is one of the most frequently used methods to establish an individual's age. The technique requires professionals to manually rate all seven permanent mandibular teeth using panoramic dental imaging in accordance with the designated atlas. To achieve the estimated chronological age, the maturity ratings of all seven teeth assigned were summed together. However, the existing technique can be a complicated procedure for a large-scale incident requiring a greater number of forensic identifications, particularly during mass disasters and the continuing COVID-19 pandemic. As a result, the existing technique entails a large number of specialists, which increases workloads and lengthens the identification process. The present practise is also arguably biased toward subjective grading, as dental age assessment is performed manually by forensic odontologists using a scoring system. The advancement of technologies in medical imaging facilitates the development of computer-based applications in which machine learning is used to leverage data mining in the medical industry to improve the reliability and speed of diagnosis while also increasing reproducibility. The semi-automated dental staging system developed in this study is based on the Malay children's population and uses a brain-inspired learning algorithm termed "deep learning". The methodology is comprised of four major steps: image preprocessing, which adheres to the inclusion criteria for panoramic dental radiographs, segmentation, and classification of mandibular premolars according to Demirjian's staging system using the Dynamic Programming-Active Contour (DP-AC) method and Deep Convolutional Neural Network (DCNN), respectively, and statistical analysis. The suggested DCNN approach underestimated chronological age with a small ME of 0.02 and 0.003 for P1 and P2, considering females and males together and introduced additional sub-stages of stages D1, D2, D3, D4, and D5. Overall, deep learning using the Tensorflow.Keras (tf.keras) application programming interface (API) makes the development of the DCNN model easier. Therefore, the proposed DCNN model was expected to assist forensic odontologists during the identification process. Besides, this semi-automated approach is also expected to provide a fast-computational time which reduces approximately 90% of human intervention. In addition, the software development based on the suggested method is currently in Technology Readiness Level 4, which means the technology has been validated in the lab. In the future, the current proposed method can be extended considering all of the seven permanent teeth and the third molar development. Also, a more sophisticated method can be achieved by performing the dental age estimation using 3-Dimensional (3D) imaging.

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CHAPTER ONE
INTRODUCTION

1.1 Research Background

Age estimation is frequently essential to estimate an individual's age due to specific reasons related to legal requirements, in prehistoric demography research, or a forensic perspective. Currently, age estimation is employed in many sectors, ranging from medical applications to forensic and legal matters. In cases of both the living and dead, loss of identity caused difficulties for both individuals and authorities. The reconstruction of the biological profile of unidentified individuals would be incomplete without the information of age. Age estimation can be performed based on the development of dentition and growth of skeleton or degenerative changes of the skeleton [1] whereby according to Ferembach et al. [2], it includes the state of dental development, the ossification state of epiphyses, the appearance of ossification centers, the obliteration of the cranial sutures, the state of the pubic symphyseal surface, and the architecture of the femoral head.

The age of living individuals and deceased bodies can be assessed based on dental maturation, using different techniques such as biochemical, morphological, histological, or developmental methods. However, living individuals' dental age estimation technique is primarily non-invasive and requires no samples extraction and laboratory examination. These methods evaluate the timing and sequence of defined growth stages of the developing dentition. Recommendations for age estimation by Schmeling et al. include dental status using the panoramic radiograph where the tooth maturity in every stage of dental development was examined, a general physical examination, and the X-ray examination of the hands [3].

Dental age estimation is mainly needed in cases where the chronological age of refugees and asylum seekers is unknown. The influx of these people to a specific region, which usually involves a developed country, was due to war, internal conflict, or natural disasters. According to the United Nations High Commissioner for Refugees (UNHCR),