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Automatic Adult Age Estimation Using Deep Learning of the ResNeXt Model Based on CT Reconstruction Images of the Costal Cartilage

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Abstract : Accurate adult age estimation (AAE) is a significant and challenging task in forensic and archeology fields. Attempts have been made to explore optimal adult age metrics, and the rib is considered a potential age marker. The traditional way is to extract age-related features designed by experts from macroscopic or radiological images followed by classification or regression analysis. Those results still have not met the high-level requirements for practice, and the limitation of using feature design and manual extraction methods is loss of information since the features are likely not designed explicitly for extracting information relevant to age. Deep learning (DL) has recently garnered much interest in imaging learning and computer vision. It enables learning features that are important without a prior bias or hypothesis and could be supportive of AAE. This study aimed to develop DL models for AAE based on CT images and compare their performance to the manual visual scoring method. Chest CT data were reconstructed using volume rendering (VR). Retrospective data of 2500 patients aged 20.00-69.99 years were obtained between December 2019 and September 2021. Five-fold cross-validation was performed, and datasets were randomly split into training and validation sets in a 4:1 ratio for each fold. Before feeding the inputs into networks, all images were augmented with random rotation and vertical flip, normalized, and resized to 224×224 pixels. ResNeXt was chosen as the DL baseline due to its advantages of higher efficiency and accuracy in image classification. Mean absolute error (MAE) was the primary parameter. Independent data from 100 patients acquired between March and April 2022 were used as a test set. The manual method completely followed the prior study, which reported the lowest MAEs (5.31 in males and 6.72 in females) among similar studies. CT data and VR images were used. The radiation density of the first costal cartilage was recorded using CT data on the workstation. The osseous and calcified projections of the 1 to 7 costal cartilages were scored based on VR images using an eight-stage staging technique. According to the results of the prior study, the optimal models were the decision tree regression model in males and the stepwise multiple linear regression equation in females. Predicted ages of the test set were calculated separately using different models by sex. A total of 2600 patients (training and validation sets, mean age=45.19 years±14.20 [SD]; test set, mean age=46.57±9.66) were evaluated in this study. Of ResNeXt model training, MAEs were obtained with 3.95 in males and 3.65 in females. Based on the test set, DL achieved MAEs of 4.05 in males and 4.54 in females, which were far better than the MAEs of 8.90 and 6.42 respectively, for the manual method. Those results showed that the DL of the ResNeXt model outperformed the manual method in AAE based on CT reconstruction of the costal cartilage and the developed system may be a supportive tool for AAE.

Keywords : forensic anthropology, age determination by the skeleton, costal cartilage, CT, deep learning
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