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Robustness Evaluation on Rotated Anterior Tooth Image of CNN Model

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Objectives Deep convolutional neural networks (CNN) have achieved breakthrough success in image classification. However, the standard CNN model is not invariant to image rotation. In the task of detecting realistic images of the oral cavity, the dentition is not always positioned horizontally. Therefore, the recognition performance of a CNN may deteriorate depending on the degree of image tilt. This study aimed to evaluate the robustness of a standard CNN for rotating images of the anterior dentition.

Methods In this study, 510 images of anterior teeth were collected from the web. In all images, the maxillary anterior teeth were in the upper part and the tooth dentition was in the horizontal direction (normal image). The images were randomly divided into 360, 50, and 100 images for training, validation, and evaluation, respectively. A 180° rotated image was created from all images (rotated image). Furthermore, the images were created by rotating the evaluation image from 5°–355° in 5° increments. A CNN model was built consisting of two convolutional, two max-pooling, and two fully connected layers based on the LeNet architecture to classify the normal and rotated images.

Results Training and validation were performed using normal and rotated images. Thus, 96% of the evaluated normal, and rotated images were correctly classified. The trained CNN was used to classify the evaluation-rotated images from 5°–355° in 5° increments. This trained CNN classified more than 90% of the 5°, 10°, 345°- and 355° rotated images as normal. More than 90% of the images rotated from 170°–200° were classified as rotated.

Conclusions The classification accuracy of over 90% of rotated images of the anterior dentition using a standard CNN was within approximately ±10° of the rotation angle.