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Extended Abstract

Fully Automatic Teeth Segmentation in Adult OPG Images †

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Abstract: In this work, the problem of segmenting teeth in panoramic dental images is addressed. The Random Forest Regression Voting Constrained Local Models (RFRV-CLM) are used to perform the segmentation in two steps. Firstly, a set of mandible and teeth keypoints are located, and then that points are used to initialise each individual tooth model. A method to detect missing teeth based on the quality of fit is presented. The system is evaluated using 346 manually annotated images containing adult-stage teeth. Encouraging results on detecting missing teeth are achieved. The system is able to locate the outline of the teeth to a median point-to-curve error of 0.2 mm.

Keywords: teeth segmentation; panoramic dental images; random forest regression-voting; machine learning

1. Introduction

Since they discovery, dental X-ray images have been widely used in a variety of clinical fields, such as abnormality detection, treatment and surgery planning, prostheses design, assessment of children's dental development, human identification and many more. Extraoral panoramic images in particular show a full coverage of the teeth as well as other surrounding bones, such as the mandible or the vertebrae. However, the quality of these images is quite challenging to automatic processing algorithms, mainly because the acquisition process is highly dependent on the patient positioning and patient movements.

2. Methods

Our main contribution is the development of a fully automatic procedure to detect and outline mandibular adult-stage teeth in panoramic dental images, and a simple method to detect missing teeth. To do that, Random Forest Regression Voting Constrained Local Models (RFRV-CLM) are used. This method combines a global linear shape model with local appearance models to locate each shape point. Full details of the method are explained in [1].

One possible approach is to build an individual model for each specific tooth. Due to the symmetry of the mouth, the teeth models of one mandible side can be used to outline the teeth on the other side. However, there are two main limitations. First of all, the search space is too big when compared with the target teeth shapes, so the teeth models needs a reasonably good initialisation. Furthermore, the teeth are very close to each other and the shapes are very similar within each tooth type (incisors, molars, etc.), so the tooth search can easily converge to a neighbouring tooth.

To overcome this problem, a two-step segmentation procedure is proposed. In the first step, a RFRV-CLM model is trained to detect a set of mandible and keypoints. This allows to capture the pose variation of teeth in relation with other teeth and with the mandible. Furthermore, the model initialization is easier due to the target shape occupies the great part of the image. In the second step, the initial shapes for each tooth model are calculated from the previous detected keypoints, and refined with the individual teeth models. Besides, a simple method based on the thresholding of the quality-of-fit per tooth is applied after the teeth shape search in order to detect missing teeth.

The full procedure was evaluated in a set of 346 panoramic images (261 images for training and 85 for testing). In each image, the shapes of seven left-mandibular teeth were manually annotated. The individual tooth models and the keypoint model were built with the RFRV-CLM algorithm. The predicted shapes of left-mandibular teeth were compared to ground truth and the performance was assessed in two ways.

Firstly, the missing teeth detection was evaluated as a classification problem with two target classes: missing (negative class) or present (positive class). The accuracy of the system was over 95%, where the precision, sensitivity and specificity were 99%, 96% and 84%, respectively.

Secondly, the accuracy of the teeth shape outlining was assessed with the point-to-curve error, which represents the shortest distance of each predicted shape point to the curve through the ground truth points. This measurement was obtained in correctly located teeth, i.e., the teeth whose predicted shapes overlaps with the ground truth shape more than 50%. The results show a median error of less than 0.23 mm for all types of teeth and the 99% ile is 1.31 mm in the worst case, which demonstrate the robustness of this procedure.

Author Contributions: N.V.B. designed and developed the experiments, analysed the results and wrote the paper. I.T.C. provided the OPG database and validated the results from a clinical point of view. M.J.C.N. helped to design the experiments and analyse the results, and validated the results from a technical point of view.

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