Supplementary Material: TANet: Towards Fully Automatic Tooth Arrangement

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1 Post-processing

In order to ensure that our results are physically feasible, we propose a post-processing module to eliminate collisions and spaces between teeth. We first construct a discrete signed distance field around each tooth. Then we are able to compute the penetration distance d between two adjacent teeth. Notice that when $d < 0$, two teeth are intersected. Inspired by Jones [1], we remove collisions and spaces by minimizing the barrier function

$$E_{collision} = (\frac{1}{1 + d/d_m})^{12} - 2(\frac{1}{1 + d/d_m})^{6}, \tag{1}$$

where d_m is the sum of the maximum internal distance of two teeth. Let $x = d/d_m \in (-1, +\infty)$, the graph of this function is showed in Figure. 1(a). This barrier function increases rapidly when $d < 0$, thus its gradient will cause separation between teeth. When two teeth are far from each other, the distance $d > 0$ and $E_{collision}$ will also get greater, but the magnitude of its gradient is relatively small, which can maintain the spatial relationship of the input. Therefore this module is able to avoid collision between teeth without creating gaps between adjacent teeth.

The effect of our simple post-processing based on physical constraints is to fine-tune the output of the neural network and make the final arrangement physical feasible, e.g. free of collision, without significant changes of positions of the individual teeth in comparison with the output of the neural network. We have evaluated our refinement module on the test set and the mean position displacement of tooth is about $0.768mm$.

2 More Results

In this section, we provide more qualitative test examples to the main paper, including the visualization of occlusion fields, critical points and a qualitative comparison between our complete method and a baseline method (NetBL+Lrecon).

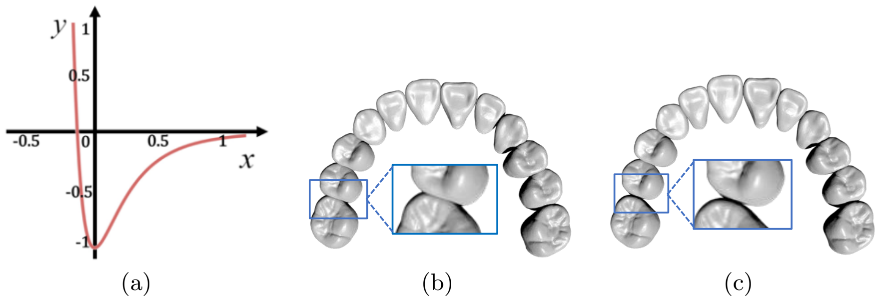


Fig. 1. (a)The graph of our barrier function for collision avoidance. (b) The output of our network; (c) Refined result from post-processing.

As shown in Figure 4, the occlusion field of the input dentition become much better than the input, and the distance between the upper jaw and lower jaw is smaller compared with the ground truth.

More examples and views of the critical points extracted by our network is shown in Figure 3.

We provide more results of our complete method (NetCom+Lcom) and the baseline method (NetBL+Lrecon) in Figure 2. The results of our complete approach are significantly better than the baseline method. The arrangement results of our complete method is more compact.

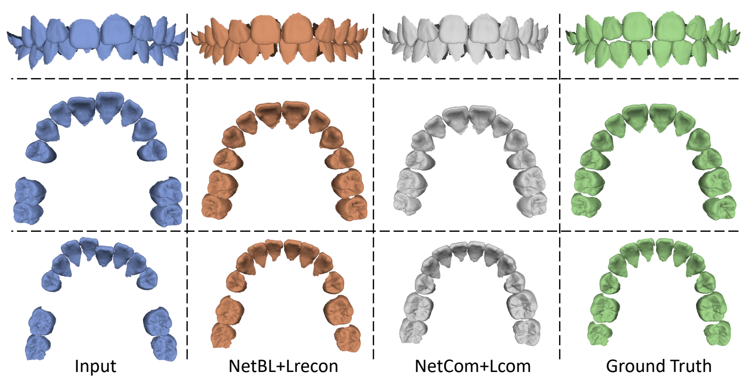
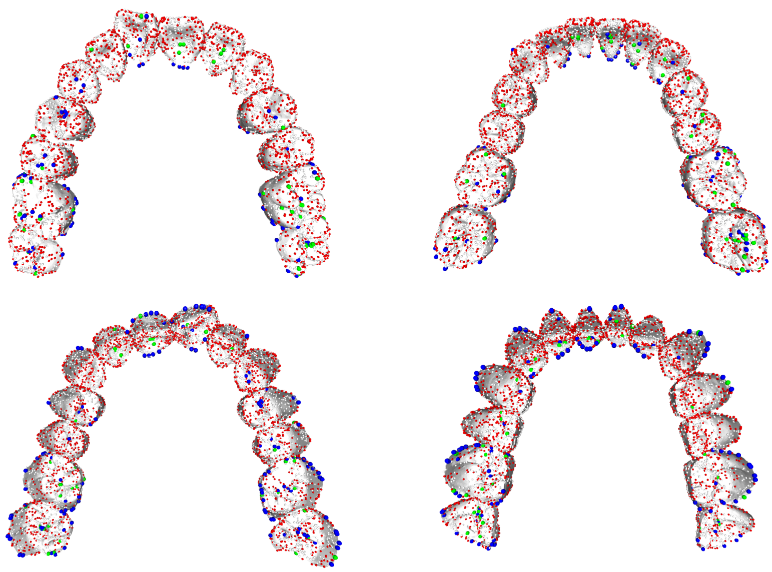
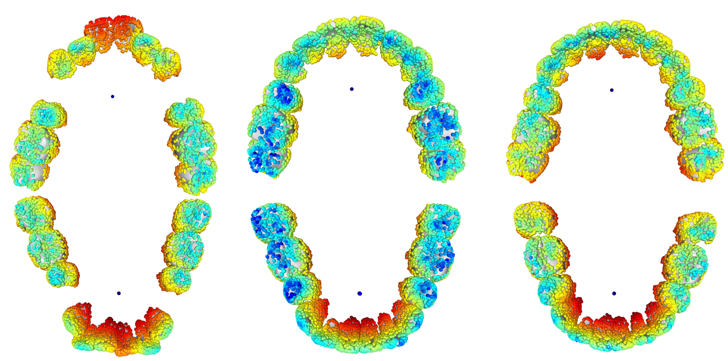


Fig. 2. A qualitative comparison between our complete method (NetCom+Lcom) and the baseline method (NetBL+Lrecon). From top to bottom, the 3 rows are the complete dentition, the upper jaw and the lower jaw of a patient respectively.



(a) (b)

Fig. 3. The visualization of critical points extracted by the network. (a) and (b) show the upper jaw and lower jaw of a patient. Top row: front side, Bottom row: back side. White: non-critical, Red: locally critical, Green: globally critical, Blue: both globally and locally critical.



(a) Input (b) Prediction (c) Ground Truth

Fig. 4. Another visualization of occlusion fields of the input, network output, and ground truth, respectively. Red: maximum distance; Green: minimum distance.

References

1. Jones, J.E.: On the determination of molecular fields.—i. from the variation of the viscosity of a gas with temperature. Proceedings of the Royal Society of London. Series A, Containing Papers of a Mathematical and Physical Character **106**(738), 441–462 (1924)