The effect of image threshold level on patient-specific segmentation of proximal tibia CT images

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Introduction: Computer-assisted orthopaedic surgery (CAOS), developed to improve the alignment of the arthroplasty components, have increased in number significantly during the last decade [1]. Some CAOS rely procedures rely on pre-operative imaging, for example, MAKO®, a market leader in CAOS, uses pre-operative CTs for pre-operative planning [2]. Segmentation is a key process in developing the required models, however, the impact of the segmentation process on the quality of the resulting model in unknown. Therefore, this study investigates the influence of the image threshold level on the surface segmentation of the proximal tibia bone.

Objectives:

- To selectively choose a threshold value that contains most of tibia bone without adjacent bones for reference 3D model
- Produce 3D model with different range of threshold value in ITK-Snap
- Compare all models with reference to see the effect of threshold value on segmentation

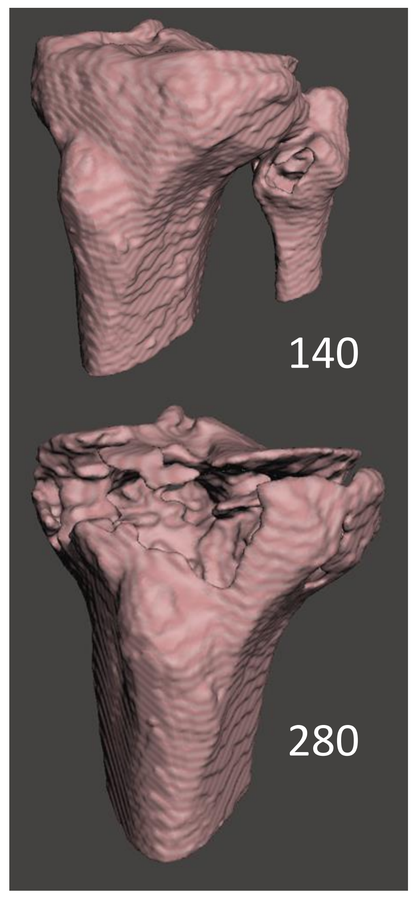

Figure 1. Example segmentations with different threshold levels

Method: A CT image of the knee joint was acquired from a single, prone participant, imported to ITK-Snap and segmented semi-automatically using the active contour (snake) and threshold method, with different threshold levels. One threshold value was subjectively chosen to be optimal and was defined as the reference model. This reference model was subsequently compared with the other segmentation levels using CloudCompare®. The mean Hausdorff distance (error) between the two point clouds was determined using the iterative closest point algorithm.

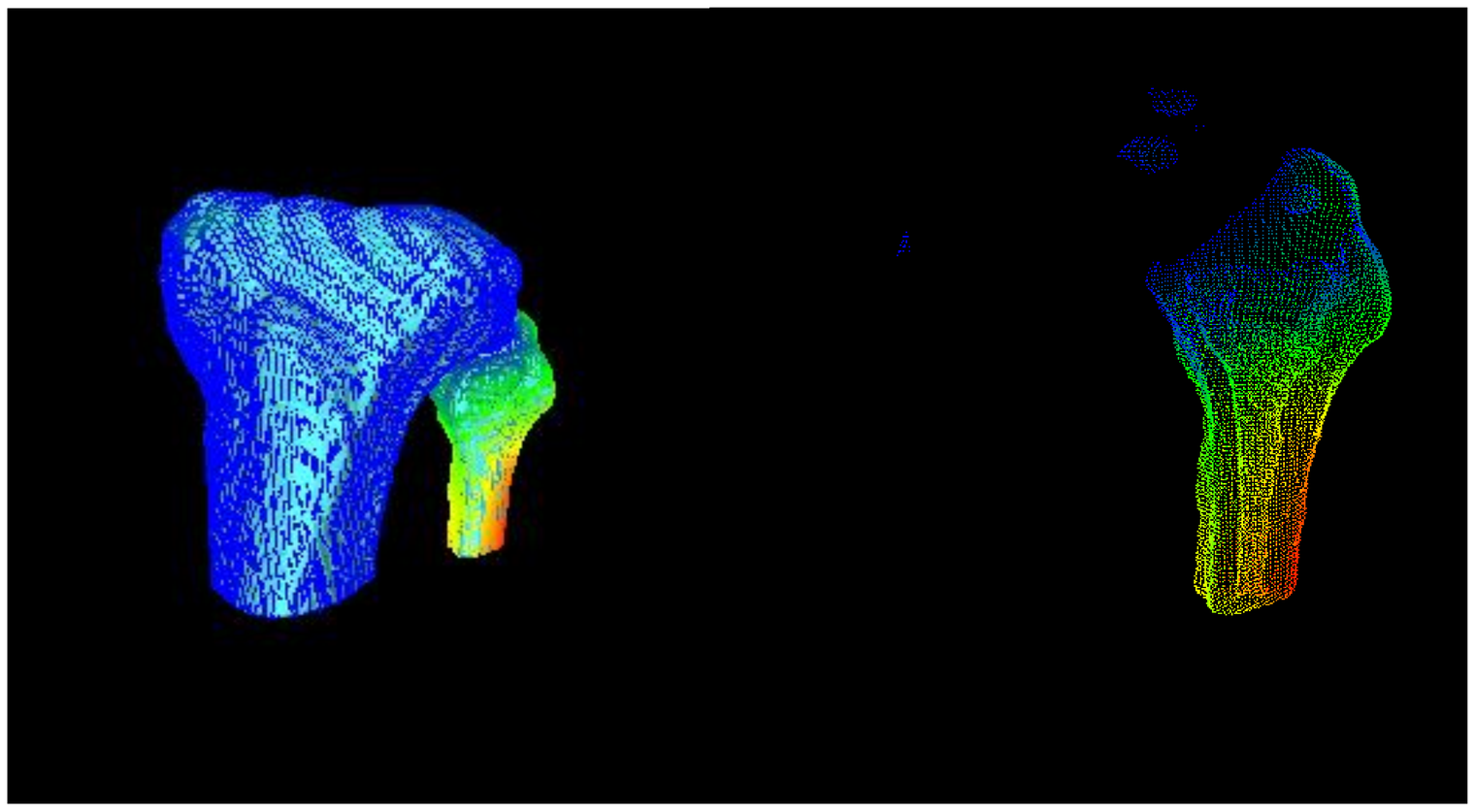

Figure 2. examples of cloud comparison and the difference. Red and Orange is the maximum difference

Results and discussion: Figure 2 exhibits the effect of changing the threshold value level on segmentation results. By decreasing the threshold level, generated contour bleeds to the surrounding soft tissue and fibula. By increasing the threshold level, more bone tissue is eliminated, increasing cavity volume. The mean error and standard deviation of cloud-to-cloud comparison is shown in Figure 3. A step change in error is apparent when contour bleeding into the fibula occurs.

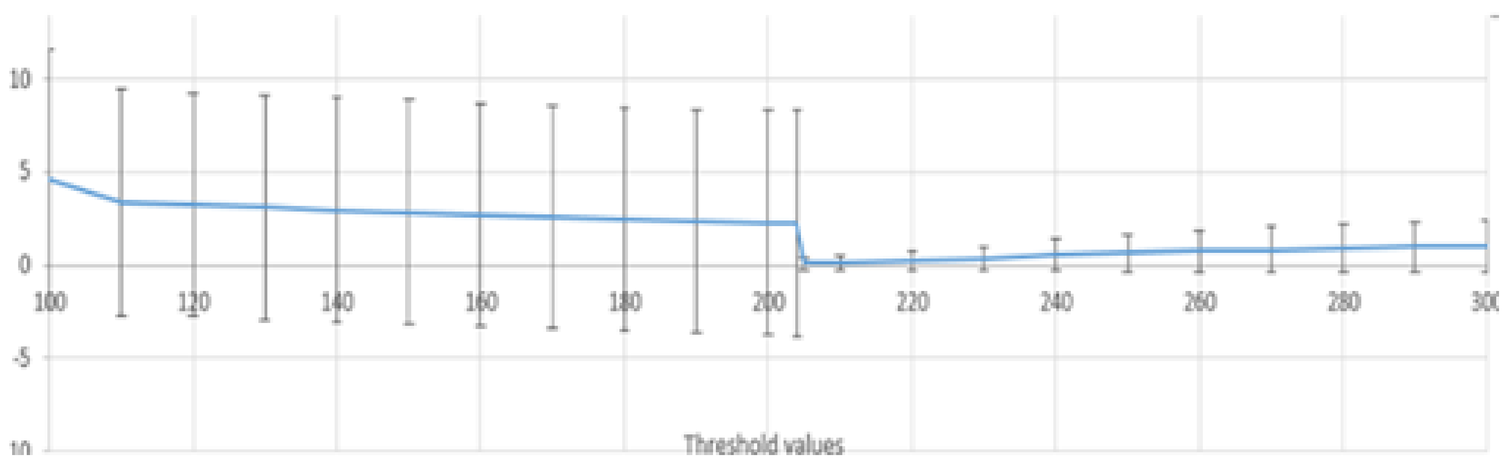

Figure 3. Comparison of tibia with different threshold value with reference tibia

Conclusion: Small changes in threshold values can result in large topographical changes, especially if bleeding occurs into adjacent bony tissue. A trade-off exists between extraneous bleeding and tibial cavity development. The effect of these not-insignificant topographical changes on pre-operative planning and/or FEA modelling is warranted.

References:
1. Picard, F., et al., Computer assisted orthopaedic surgery: Past, present and future. Med Eng Phys, 2019. 72: p. 55-65.
2. Naoki Nakano, e.a., Why are patients dissatisfied following a total knee replacement? Asystematic review. International Orthopaedics, 8 July 2020. 44: p. 1971–2007.