Review of Master's Thesis:
"Reconstruction of a patient-specific surface model of the humerus bone"
Jan Hereš
Supervisor: Dr. Eva C. Herbst

1) Originality of the work and related works

The goal of this thesis was to reconstruct the distal humerus from the proximal humerus. Although previous studies attempted this, this project focused on testing new deformable registration methods and implementing them in 3D Slicer. No solution was clear from the beginning. Regarding available resources and support: humerus models were landmarked by me, and our collaborator Arthur Porto proposed initial ideas for mesh registration methods. The task of the thesis was quite broad and challenging because Jan not only needed to perform a lot of technical tasks (implementing different meshing algorithms, creating 3D Slicer GUI) but also needed to learn the anatomy of the humeri models and the clinical context. I also want to emphasize that while I could help with landmarking and the anatomical considerations and clinical goals, I do not have a deep knowledge of computer science, so Jan was working very independently on those aspects (especially implementation of BCPD in 3D Slicer, OS compatibility, and GUI development).

2) Student engagement & his collaboration with you, his supervisor

Jan's engagement was excellent. He was very motivated and came up with good ideas on his own (e.g. the idea to cap the ends of the meshes to test whether this was causing the RANSAC misalignment). Jan was also quick and thorough in implementing the changes I suggested for the thesis in the last weeks.

3) Quality of the solution

The 3D Slicer GUI is very user friendly and works smoothly. The weakness of the solution of the shape reconstruction of the humerus is two-fold. First, there are issues with the RANSAC initial alignment (see section 4 for solutions). The second weakness is the issue in reconstructing the humeral length, which has also been an issue in previous publications. I do not see these weaknesses in the reconstruction results as a weakness of the thesis, since Jan clearly states the limitations in the thesis, as well as solutions that were already tested (i.e. cropping distal humerus), and future directions. The strength of the solution is that Jan's implementation in 3D Slicer makes it very easy to test adjustments to the method to improve performance, and makes the method very accessible. The main weakness I saw in the thesis is the lack of quantitative comparisons of the reconstructed model and the original morphology (see notes section 5).

4) Usability / reusability of the solution

We have already discussed several next steps for improvement of the RANSAC alignment and length reconstruction. These include the ideas presented in the thesis, as well as an idea I had on adjusting the RANSAC alignment criteria to be based on normals calculation instead of closest distance, which I think can solve the alignment issues. After these adjustments, we would like to publish the thesis as a journal paper if we get satisfactory results for the humerus reconstruction. We also intend to share Jan's 3D Slicer module openly since we believe it can be very useful for a broad range of mesh reconstruction tasks. I am also actively searching for grants to try to obtain funding to hire Jan part time as a research assistant because I would really like to continue working with him.

5) Research plan completeness

The thesis addresses all steps of the research plan. For the analysis of the results, I would have liked to see quantitative testing of the reconstructed results, instead of just a qualitative comparison. I realize that this was likely due to running out of time (as mentioned above, the thesis was quite broad and included many tasks). This is my main recommendation for improvement – I think Jan should have prioritized the analysis of the results at an earlier

stage and added metrics such as length difference, as well as using the 3D shape comparison using 3D Slicer's DeCa module. If not possible time wise, at least more discussion of future quantitative comparison methods would have been good. Furthermore, some discussion of how our results and methods compare against previous works would have been good.

I assign this thesis a grade of 93 points (grade A, equivalent to "excellent") and recommend the thesis for defense.

Dr. Eva C. Herbst, Zürich, 21 May 2024