COMPUTING AVERAGE ANATOMICAL IMAGES: COMPARISON BETWEEN THIN PLATE SPLINE AND LOG-EUCLIDEAN APPROACH

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Introduction

Nowadays orthopaedic implants are designed on few cadaver bones, limiting the optimal fitting of the implants to a reduced number of patients. A different approach could be the medical image-based one, which allows to take into account a bigger number of bones and also to quantify bone characteristics in an automatic way.

In this work we propose a pipeline to calculate the average femur from CT images, comparing the results obtained with two different techniques: Thin Plate Spline (TPS) [Bookstein, 1989] and Log-Euclidean diffeomorphic transformation [Pennec, 2008].

Methods

The pre-processing steps of the pipeline are the same for both approaches. First rigid registration is performed to align all the bones in the same coordinate system. Then affine registration is calculated to scale the bones to the reference bounding box. Non-rigid registration is then computed to find the anatomical correspondences among the bones. Finally the reference bone is propagated with the average intensities and warped to the mean shape. The warping from reference to mean shape is object of this comparison.

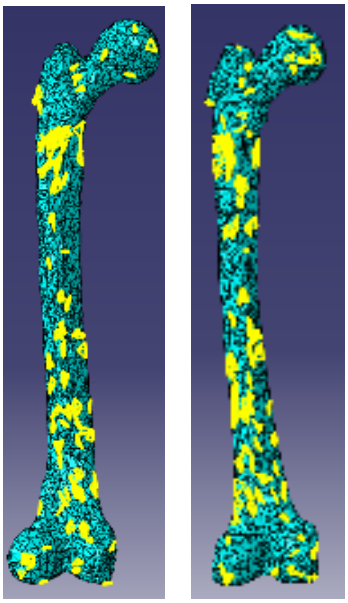
For the TPS pipeline the reference bone containing the mean intensity is deformed into the mean shape using a point-based warping that uses spline based functions to create the deformation vector field. On the other side, the same reference bone with average intensity is warped into the mean shape using the Log-Euclidean framework that allows the calculation of a mean diffeomorphic deformation vector field from the average velocity field.

The analysis of the results was done by comparing the smoothness of the two different vector fields in terms of Jacobian determinants and quality of the mesh propagation from the reference image to the two new bones.

Results

The comparison of the determinant of the Jacobian of the two deformation vector fields did not show relevant differences in terms of average, standard deviation and minimum value, while differences were observed for the maximum value, which is higher for the Log-Euclidean case.

The mesh comparison executed using the mesh evaluator in ABAQUS™ (ABAQUS Inc., Providence, RI, USA), did not show relevant differences between the mesh generated from the TPS and the one from the Log-Euclidean deformation vector field.



(a) *(b)*

Figure 1: Comparison between the meshes generated as propagation from the reference bone: (a) use of the TPS, (b) use of the Log-Euclidean. The yellow elements are considering as critical elements by ABAQUS.

Discussion

The results show a difference between the two methods in terms of maximum of the Jacobian determinant. This suggests that the Log-Euclidean method is more powerful in capturing large differences than the TPS one. Therefore the two methods will be tested and compared in cases in which the deformations involve bigger differences between the reference and the bone to be calculated.

References

Bookstein, IEEE T Pattern Anal, 11(6):567-585, 1989.
Pennec, ETVC, 5416:347-386, 2008.