AN ITERATIVE METHOD FOR FEMUR MORPHING USING STATISTICAL SHAPE MODELS

[1, 2] Yuhui M Yang, [2]Daniel Rueckert and [1]Anthony MJ Bull
[1]Department of Bioengineering, Imperial College London,
[2]Department of Computing, Imperial College London; email: a.bull@imperial.ac.uk

INTRODUCTION

Bone morphing is an extrapolation procedure that can be used for intra-operative visualisation of bony structures in image-free surgeries. It enables a complete surface to be reconstructed from sparse 3D digitised landmarks or surface points on the bone, or discrete bone segment data. The aim of this study was to develop an accurate morphing method based on the use of statistical shape modelling (SSM) and an iterative optimisation.

METHODS

A 3D SSM for a set of femora was built. For a global transformation, rigid registration was applied to align all shapes into a common coordinate system using the iterative closest point (ICP) algorithm [1]. When registering the femora, the centre of translation and rotation is the centre of the femoral head instead of the centre of the point cloud. Point-to-point correspondences were established using non-rigid registration based on multi-resolution B-spline free form deformation [2]. Principal component analysis was then performed to estimate the morphological variations.

The morphing procedure involves two steps: global rigid registration and local morphological deformations. Given a set of sparse points on a femur surface which was excluded when building the SSM, the ICP algorithm was applied to register the point cloud to the mean shape of the model. The deformation procedure is formulated as a linear equation system and the solution to the system is a set of weights on the principal components that best fit the deformed shape to the point cloud [3]. Starting from the mean shape which has zero weights on all principal components, a new shape fitting the point cloud is reconstructed by changing the new weights of the principal components. The fitting procedure was implemented iteratively until the root mean square (RMS) distance between the point cloud and the resulting surface was smaller than a pre-defined threshold.

RESULTS AND DISCUSSION

24 adult femora were CT scanned. Their outer surfaces were segmented manually and then converted into 3D triangulated mesh surfaces using the marching cubes algorithm. One femur was taken out and the remaining 23 were used to build the shape model. Figure 1 shows the first two principal modes of the dataset. Length is the first component and the extension of the femoral neck is the second component.

To create a set of sparse surface points, crest points were extracted automatically from the femur that was excluded from the shape model. This significantly reduces manual interaction. Figures 2 and 3 show the results of the rigid alignment of the point set and the reconstructed surface. A leave-one-out validation was performed. The average RMS distance between the reconstructed surfaces and the real surfaces is 2.82mm; the standard deviation is 1.11mm.

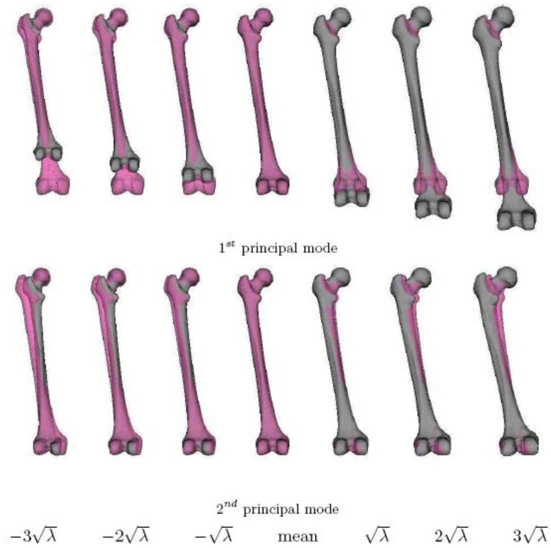

Figure 1: Shape variations of the first two principal modes.

Figure 2: Surface points aligned to the mean shape.

Figure 3: A reconstructed surface.

CONCLUSIONS

An improved optimization method for bone morphing was introduced. It iteratively deforms the reconstructed shape to a cloud of surface points until convergence. Results of the leave-one-out validations indicate that the reconstructed surfaces can predict the whole surface accurately from a set of sparse points.

REFERENCES

1. Besl PJ, et al., *IEEE Trans. Pattern Anal. Mach. Intell.* **14**:239-356, 1992.
2. Rueckert D, et al., *IEEE Trans. Med. Img.* **18**:712-721, 1999.
3. Rajamani KT, et al., *ISBI*, 1255-1258, 2004