Automatic segmentation of the humerus from CT volumes using statistical shape models and Markov Chain Monte Carlo methods

Fouefack Jean R[1,2,3,4]., Borotikar Bhushan[1,3,4]., Burdin Valérie[1,2,3,4], Douglas Tania S.[1] and Mutsvangwa Tinashe E.[1,2,3]

1. *Division of Biomedical Engineering, University of Cape Town, South Africa; 2. IMT-Atlantique, France; 3. INSERM U1101 LaTIM, France; 4.* University of Western Brittany, Brest, France.

IMT Atlantique
Bretagne-Pays de la Loire
École Mines-Télécom

Abstract

Three-dimensional volumes are important tools in the clinical community. However, efficient extraction of useful information from these images remains a challenge in the medical imaging field. This project aims to develop automatic tools to improve the reproducibility and speed of the surgery planning, and provide accurate patient-specific ancillaries for prostheses pose guiding. This study specifically focuses on the development of an automatic method to segment the humerus from CT volumes.

Introduction

Segmentation of the humerus bone from computed tomography (CT) is of interest in prosthetic design and computer-assisted orthopaedic surgery of the upper limbs [1].

Common methods for bone segmentation are semi-automatic and need manual intervention [2].

Such manual extraction of humerus features is time-consuming and is prone to inaccuracy especially when performed on low-resolution images.

Materials and Methods

1. *Building of the active shape mode (ASM) from 9 humeri segmented from CT images.*
2. *Rigidly registering the CT image and the mean of the SSM in order to align them.*
3. *Fitting the SSM to the CT image edges, then sampling the profile normal of the current mesh.*
4. *Designing a Markov chain Monte Carlo method to obtains a sample of the desired distribution by observing the chain after a number of iterations.*

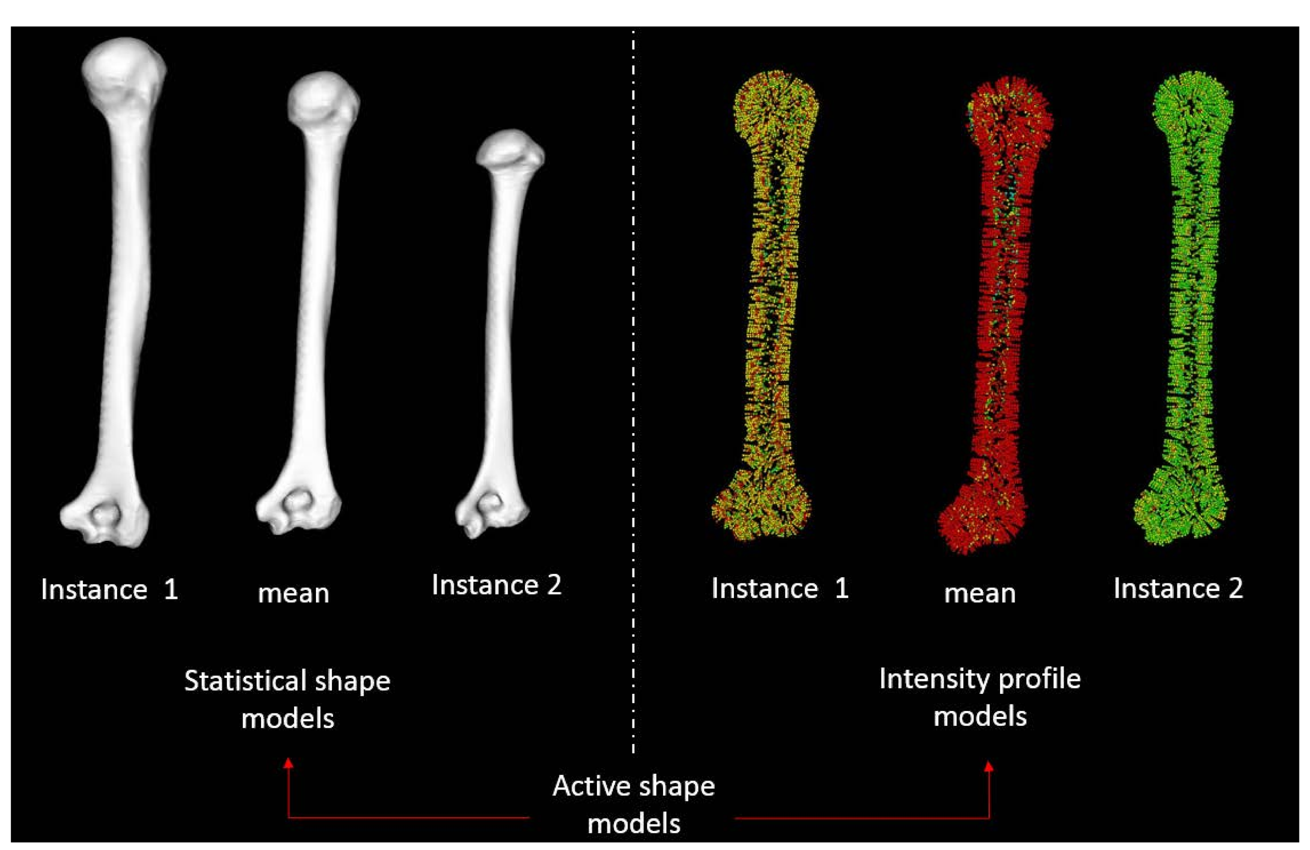

Figure 1: Active shape models (ASM) components. *Left: SSM represented by its mean and two other instances. Right: Intensity profile models represented by its mean and two other samples.*

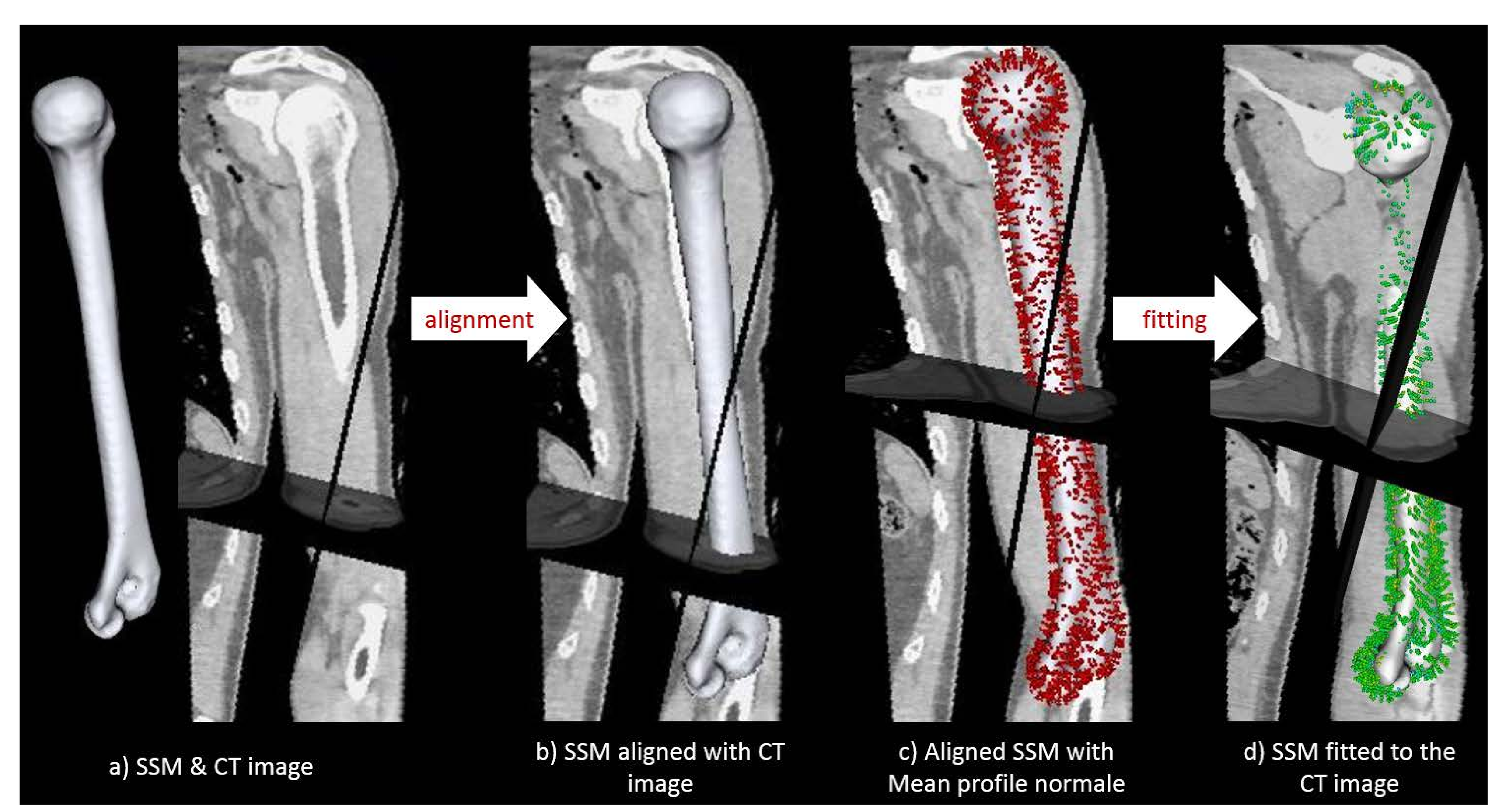

Figure 2: The protocol to segment the humerus from the CT image. *Left: Alignment of the mean SSM with the CT image; right: Fitting the SSM to the CT image edges, then sampling the profile normal of the current mesh points (green points in 2d) and comparing with the mean intensity profile (red points in 2c) trained by the intensity model in a probabilistic way [3].*

- The posterior model from the current state (state with parameter Θ) is computed as:
- $$P(\Theta|\text{CT image}) = \frac{P(\Theta)P(\text{CT image}|\Theta)}{P(\text{CT image})}$$

Where Θ is the shape parameter ; p(Θ) is the prior ; p(CT image|Θ) is the likelihood; p(CT image) is the target distribution.

This work is based on research supported by the National Research Foundation (NRF) of South Africa (grant no's 105950 and 114393); the South African Research Chairs Initiative of the NRF and the Department of Science and Technology (grant no 98788), and the Medical Research Council of South Africa.

Results

The Hausdorff distances (HD) were computed between seven automatic segmented mesh surface and their corresponding manually segmented CT images.

The HD distance errors obtained are summarised in table 1 and the average was 2.09±0.51 mm, which is relatively small.

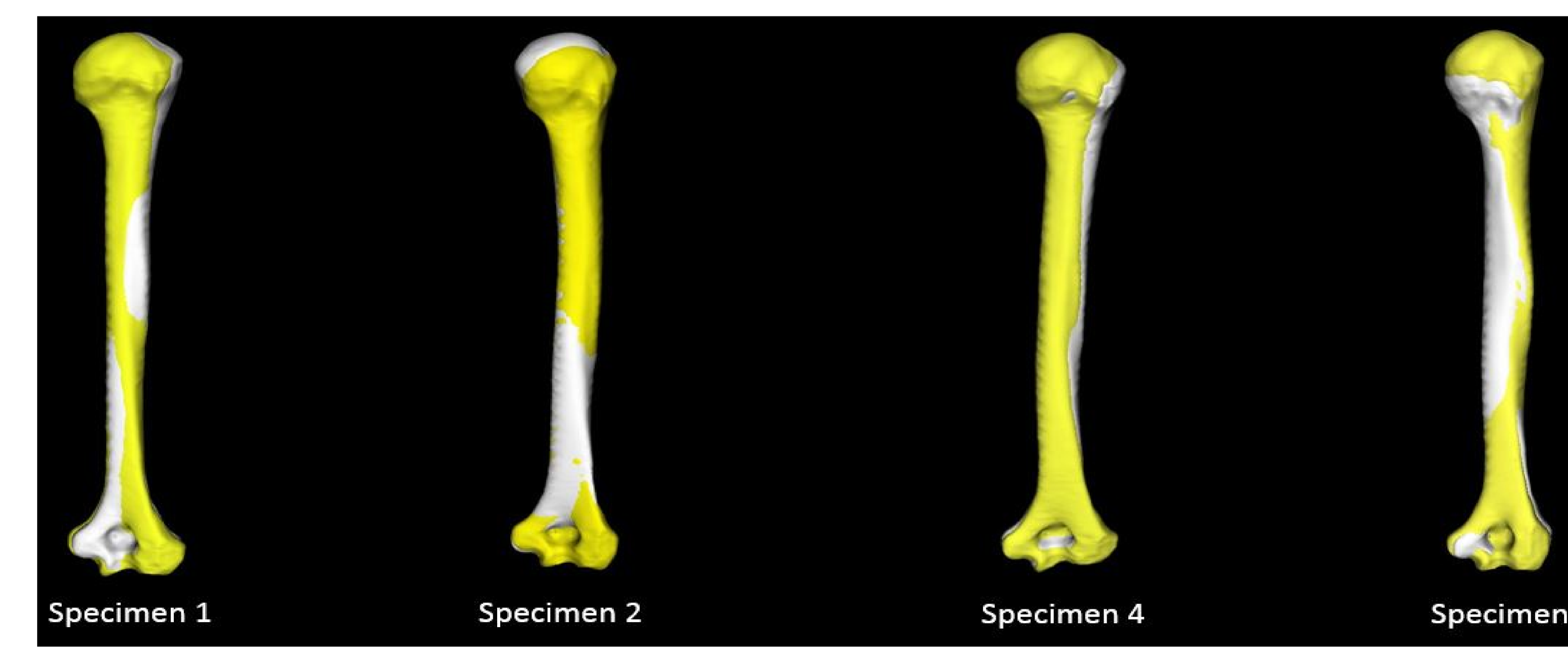

***Figure 3:** Four individual specimens segmented (gray) superimposed with their corresponding manually segmented one (yellow).*

Table 1: Seven individual humeri HD errors

Specimen	1	2	3	4	5	6	7	Mean	STD
HD (mm)	1.68	2.69	2.62	1.35	1.80	2.10	2.40	2.09	0.51

Discussion and Conclusions

The developed segmentation method automatically detects the edges of the humerus bone in the target image.

The pipeline is robust, and aside from the initialization, requires no further user input.

References

1. Younes, LB et al., "Fully automatic segmentation of the femur from 3D-CT images using primitive shape recognition and statistical shape models." *International journal of computer assisted radiology and surgery* 9, no. 2 (2014): 189-196.
2. Almeida, DF et al., "Fully automatic segmentation of femurs with medullary canal definition in high and in low resolution CT scans." *Medical Engineering and Physics* 38, no. 12 (2016): 1474-1480.
3. Cootes, T et al., "An introduction to active shape models." *Image processing and analysis* (2000): 223-248.

Contract email : fjrassaire@gmail.com

medical image inferencing & distributed diagnostics