BUILDING A STATISTICAL ANATOMICAL MODEL OF CALCANEUS

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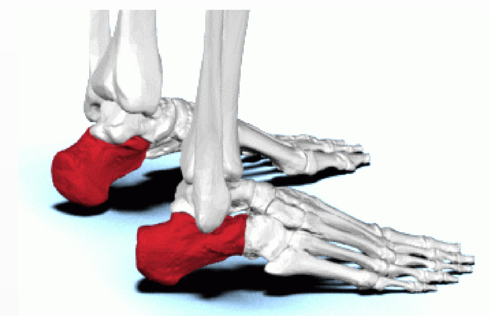
Introduction

Calcaneus (heel bone) is a bone that gives a support function for motion of human body. Fractures of calcaneus constitute about 60% of foot injuries. Understanding of calcaneus shape and structure is needed to solve many research problems connected with the treatment of calcaneus injuries. Basically, the mathematical description of this bone can be applied in image understanding and numerical simulations e.g. in recognition and modeling of bone fractures.

Purpose

To model the shape of calcaneus using computer tomograhy (CT) scans.



Methods

The basics steps of the proposed methodology are show on the diagram below.

Collect CT Scans → Contrast Enhancement (Sigmoid Function) → Bone edge extraction (Region Growing) → Building 3D model → 3D model (Spherical Harmonics)

CT scan images are processed through contrast enhancement using sigmoid function: $S(t) = \frac{1}{1+e^{g(c-t)}}$, where g is a gain, and c is cutoff value [1]. Next, the region growing algorithm is applied on each slice from the CT scan. The coordinates of the bones edges are taken. On their basis the surface of the bone can be described using the series of spherical harmonics [2]. The complete complex-valued spherical harmonics are given by:

$$Y_l^m(\theta,\phi) = N_l^m P_l^m \cos(\theta) e^{Im(\phi)}, l \geq 0, |m| \leq l \qquad (1)$$

where N_l^m is the normalization factor defined as:

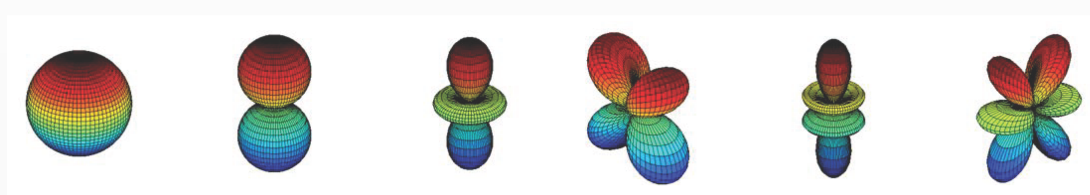
$$N_l^m = \sqrt{\frac{(2l+1)(l-m)!}{4\pi(l+m)!}} \qquad (2)$$

P_l^m are the associated Legendre functions:

$$P_l^m(x) = \frac{-1^m}{2^l l!}(1-x^2)^{m/2}\frac{d^{l+m}}{dx^{l+m}}(x^2-1)^l \qquad (3)$$

The output is the polynomial whose coefficients are characteristic for the analysed shape. The real-valued spherical harmonics can be expressed as:

$$y_l^m(\theta,\phi) = \begin{cases} \sqrt(2) N_l^m P_l^m \cos(\theta)\cos(m\phi), m > 0 \\ \sqrt(2) N_l^m P_l^m \cos(\theta)\sin(m\phi), m < 0 \\ \sqrt(2) N_l^0 P_l^0 \cos(\theta), m = 0 \end{cases} \qquad (4)$$



Results

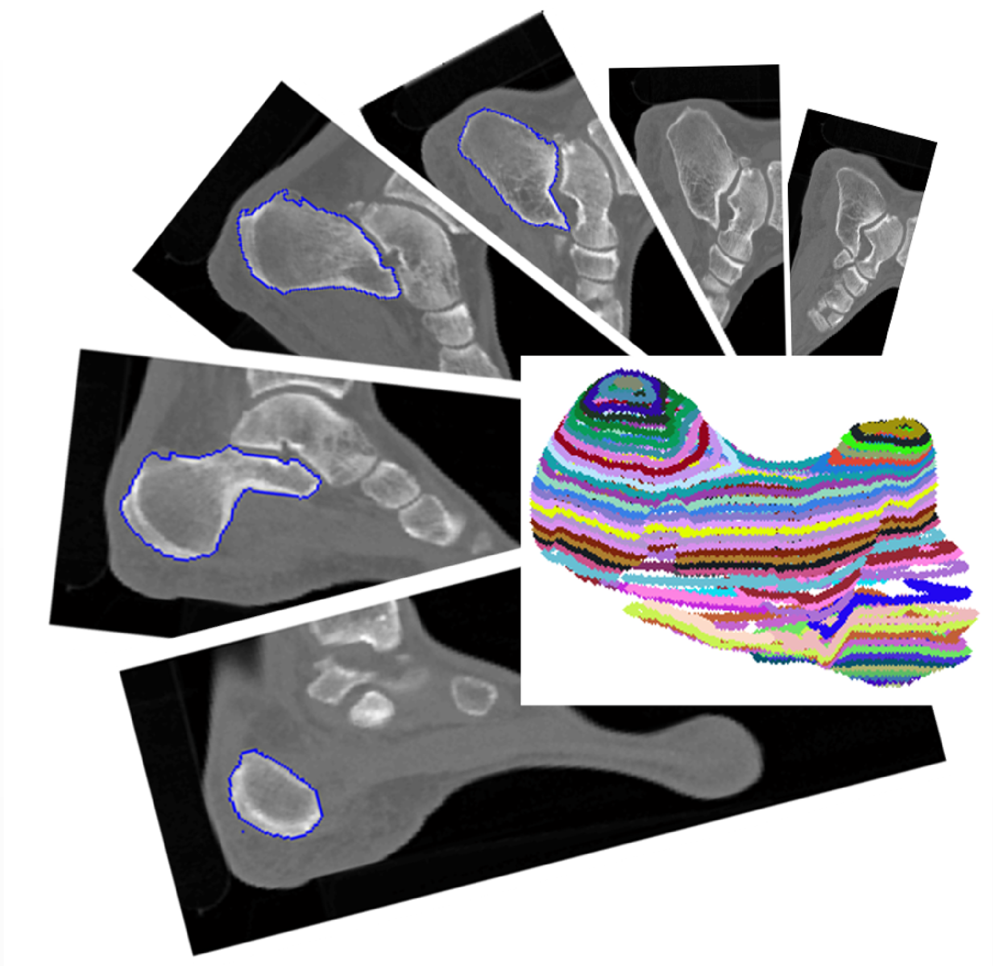


Fig.1. An example of modeling

The shape characteristics are assessed through the polynomial coefficients assessment. We tested six pairs of feet to assess the differences between left and right foot.

Tab.1. RMS group statistics

	LEFT FOOT	RIGHT FOOT
MEAN	0.0015	0.0232
SD	1.57E-08	0.0008
Sig. (2-tailed)	0.094	

No statistical significance was found (t-test, $p<0.05$).

Conclusions

This pilot study shows that modeling of tissue structures is possible using proposed methodology. However, the statistical description of calcaneus will be more reliable when we test more cases. This will lead to the first statistical anatomical atlas of calcaneus.

References

[1] http://www.csse.uwa.edu.au/~pk/research/matlabfns/
[2] Iskander, D.R. , Modeling videokeratoscopic height data with spherical harmonics ' s Title, in *Optometry Vision Science*, 86.5 (2009): 542-547.

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