

Quantification of Arthritis Progression From CT Images

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Quantification of Arthritis Progression From CT Images

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1. Introduction

To quantify the amount of damage done to the bone structure by collagen induced arthritis [1] in mice we perform the following steps:

Texture Based Segmentation The raw data is segmented using a combination of filtering and K-means to extract regions with similar texture, i.e. bone and background.

Orthogonal Slices As the raw data is not displaying the correct bone cross section we construct new slices that are orthogonal to the direction of the bone.

Cortical Bone Thickness We are correlating the cortical bone thickness with different stages of arthritis.

Bone roughness Using a marching cubes algorithm we are considering the roughness of the surface.

2. Data

Top row: A 3D reconstruction of a non-arthritic paw from a mouse and five sequential CT images that are used for the reconstruction. The reconstruction is made using Defines8.

Bottom row: A 3D reconstruction of an arthritic paw from a mouse and five sequential CT images that are used for the reconstruction.

3. Texture Based Segmentation

The N_y filters, F_i , are convolved with the images, J . This result in the original $M \times N_x$ image being transformed into a $M \times N_x \times N_y$ data set. Filters used are from [2].

Pixels are clustered using K-means algorithm based on their filter responses. By setting $K = 2$ we get a segmentation into foreground and background.

4. Orthogonal Slices

The original CT images are parallel to the $x-y$ plane, see Data panel. We are looking for slices that are orthogonal to the bone by finding the coordinate system x', y', z' . The orthogonal slices are used to determine the thickness of the cortical bone.

Clockwise from top left we have the original image, the original data transformed, so that we have an orthogonal slice around the bone marked in red (top left) and finally the segmentation of the orthogonal slice showing the true cross section of the bone.

5. Bone Roughness

The roughness is determined by the average angle between surface normal vectors. The left images show a non-arthritic paw and the right an arthritic paw [3]. The histogram of angles (left) gives a quantitative description of the roughness of the bones. The surface is generated using Defines8.

6. Cortical Bone Thickness

The minimal thickness of the cortical bone of the ring finger metatarsal from four non-arthritic (left) and three arthritic mice (right). The minimal thickness is found as the smallest distance between inner and outer perimeter in the orthogonal slices. Close to the joint between the metatarsal and proximal phalange (leftmost in both plots) the arthritic bone has considerably thinner cortical bone.

Outlook

Improve the measuring of cortical bone thickness, mainly through improved bone tracking close to joints. Validating the roughness measures by controls. Combining the measures and construct an algorithm for evaluation of disease diagnosis and progression. Adapt the algorithm for rheumatoid arthritis so that it can be used clinically.

References

[1] Brand *et al.*, "Collagen-induced arthritis", *Nat. Protoc.* 2(5), 2007.
 [2] Malik *et al.*, "Contour and Texture Analysis for Image Segmentation", *IJCV*, 43(1):7-27, 2001.
 [3] Silva *et al.*, "Application of Surface Roughness Analysis on Micro-Computed Tomographic Images of Bone Erosion: Examples Using a Rodent Model of Rheumatoid Arthritis.", *Molecular Imaging*, 5(4):475-484, 2006.

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