Leibniz Institute for Natural Product Research and Infection Biology - Hans Knöll Institute

Quantification of Arthritis Progression From CT Images

Carl-Magnus Svensson[1], Bianca Hoffmann[2], Ingo Irmler[3], Thomas Kamradt[3], Hans Peter Saluz[2] and Marc Thilo Figge[1,4]

[1]Research Group Applied Systems Biology, HKI, [2]Cell and Molecular Biology, HKI, [3]Institute of Immunology, University Hospital, [4]Friedrich Schiller University, Jena

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:

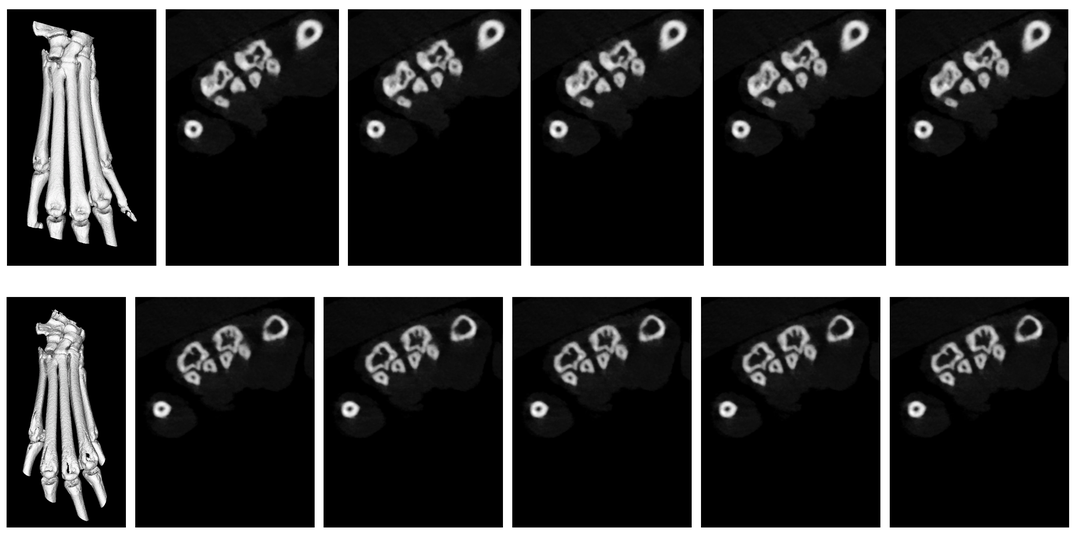
Texture Based Segmentation The raw data is segmented using a combination of filtering and K-means to extract regions with similar texture, i.e. bone and background.

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.

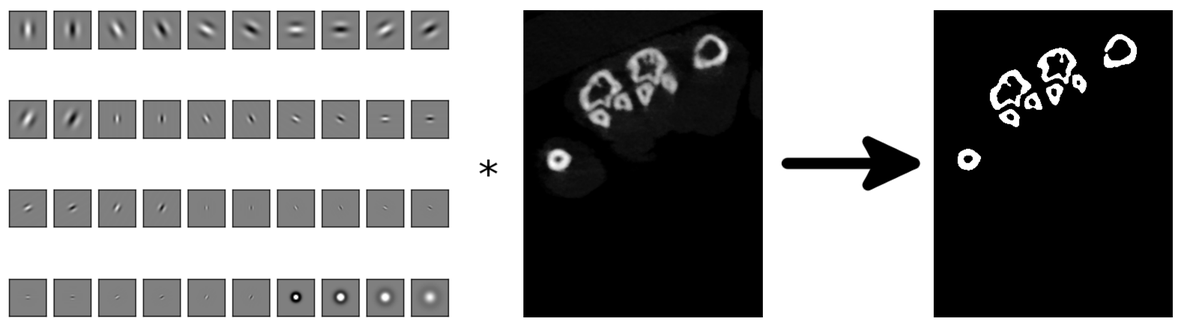
2. Data



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 Definies®.

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

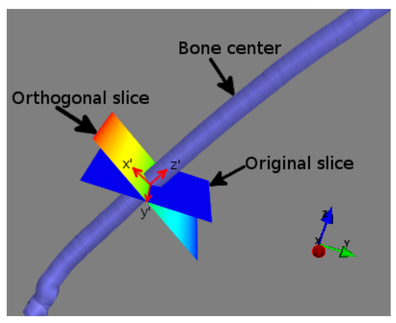
3. Texture Based Segmentation

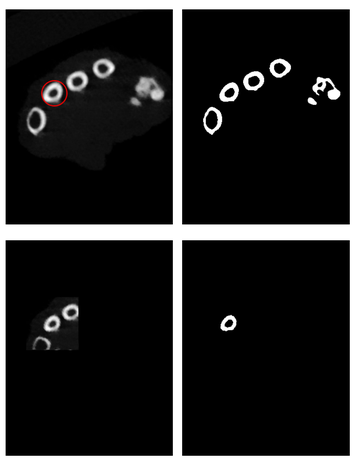


The N_F filters, F, are convolved with the images, I. This result in the original $M \times N$ image being transformed into a $M \times N \times N_F$ data set. Filters used are from [2].

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

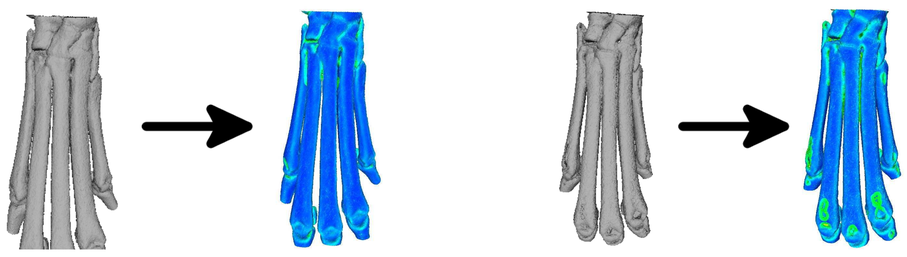


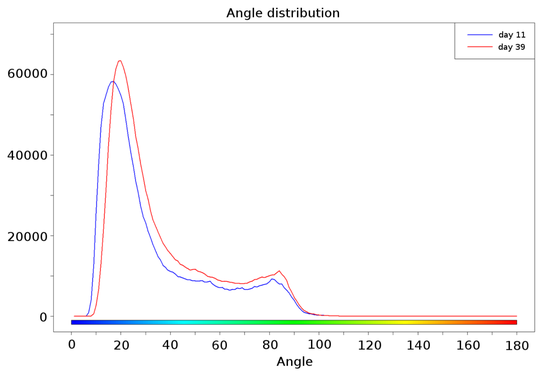


The original CT images are parallel to the x-y plane, see Data panel. We are looking for slices that are orthogonal to the bone by finding the coordinate system x'-y'-z'. The orthogonal slices are used to determine the thickness of the cortical bone.

Clockwise from top left we have the original image, the segmented images, 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.

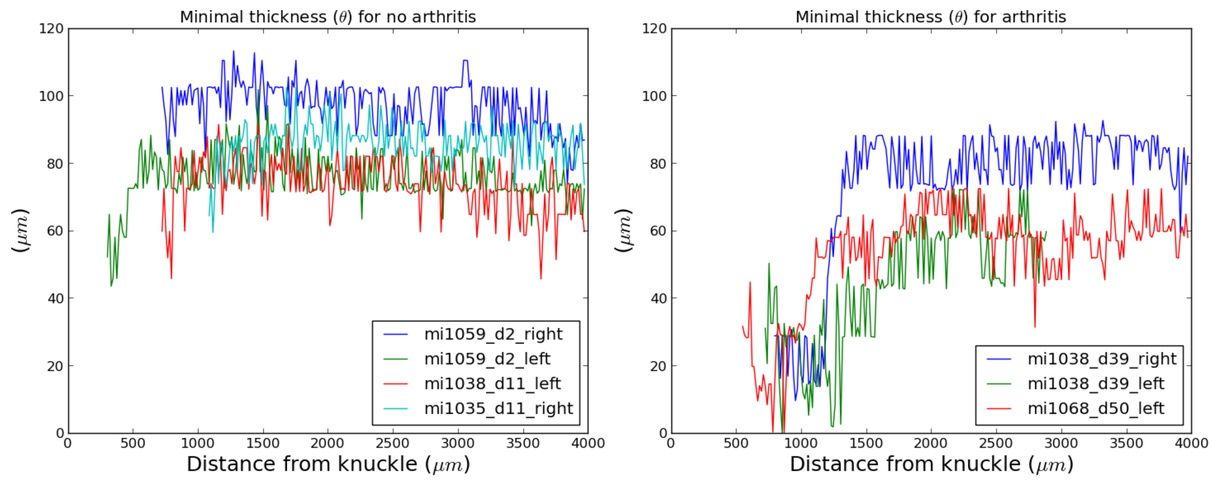
5. Bone Roughness





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 Imaris®.

6. Cortical Bone Thickness



The minimal thickness of the cortical bone of the 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", *IJVC*, 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.

Contact: carl-magnus.svensson@hki-jena.de