Segmentation and 3D imaging of cartilage tissues

in mouse embryo head

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Abstract

Understanding face developmental processes requires accurate 3D visualisation of the entire embryo head. This study is realised on the cartilage structures in the head at the end of the embryonic stage of mice. X-ray computed microtomography (microCT) [1] has the potential to produce high resolution quantitative 3D imaging of such a small biological sample. Even with the best staining procedure which produce differential soft tissue contrast, the cartilage has a low detectability in the tomographic image and the segmentation has to be done manually.

We present the automatic segmentation method of the cartilage tissue of olfactory system in microCT data. This method is based on the 3D region growing method [2] and dynamic thresholding criteria. The quality of an input data is important for a reliability of the segmentation method. For this purpose the Canny's edge detector [3], which belongs to more advanced detectors and less sensitive to noise, is used.

The closing (morphological) operation was applied on the segmented region to remove small holes inside of the region.As the region growing algorithm generate big errors on the large volume data, the algorithm was applied on the partial data volume.

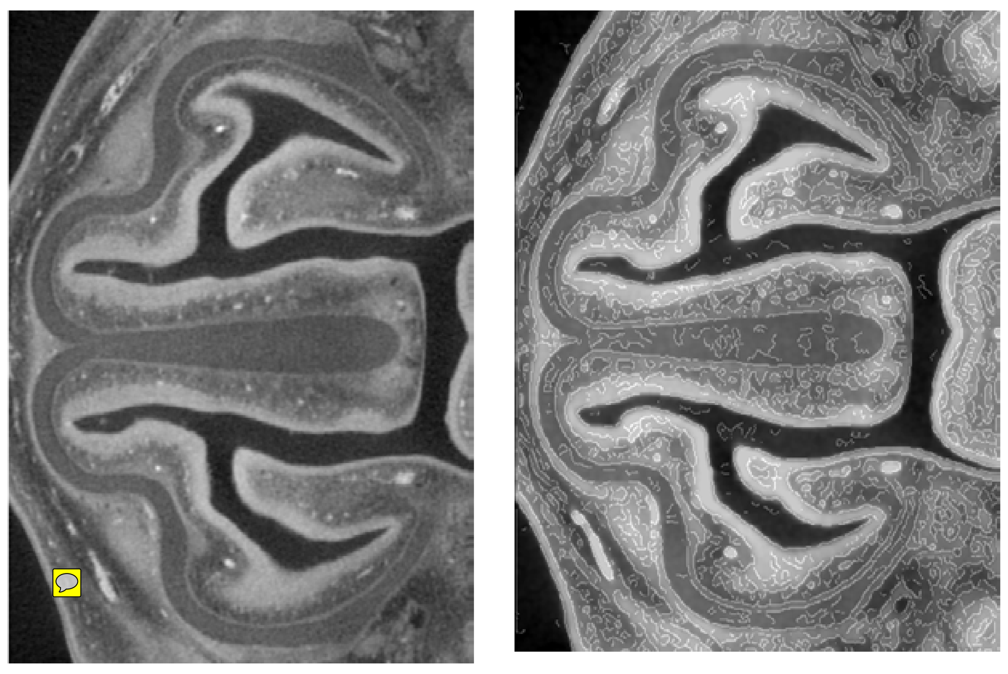
The segmentation procedure is demonstrated on 14 day and 16 day mouse embryo. The samples were stained by phosphotungstic acid (PTA) [4] and embedded in agarose gel. The CT measurement were conducted using an industrial system GE phoenix v|tome|x L 240 equipped with a 180 kV/20W maximum power X-ray nanofocus tube. 3D models were created from the segmented regions and compared the reference model done by manual segmentation. The proposed segmentation marked almost entire the cartilage structure but the operator intervention is still needed especially at the end of the structure where the cartilage boundary is unclear. However, the automatic approach saves a significant processing time.

Canny's edge detector

Canny's edge detector is used for preprocessing of CT data. This detector belongs to more advanced detectors and is less sensitive to noise. Edge detector transform grayscale images to a binary form but the binary image is not suitable for the region growing. By summing of the binary edge image and weighted grayscale image are obtain grayscale images with enhanced edges, see equation 1.

$$g(i,k)= w\, f(i,k)+b$$

This approach of preprocessing has proved as the most suitable for the region growing. A sample of the preprocessed image by using this method can be seen in figure 1. The following figures shows differences between original image and image preprocessed by using Canny's edge detector.



Implementation of the region growing

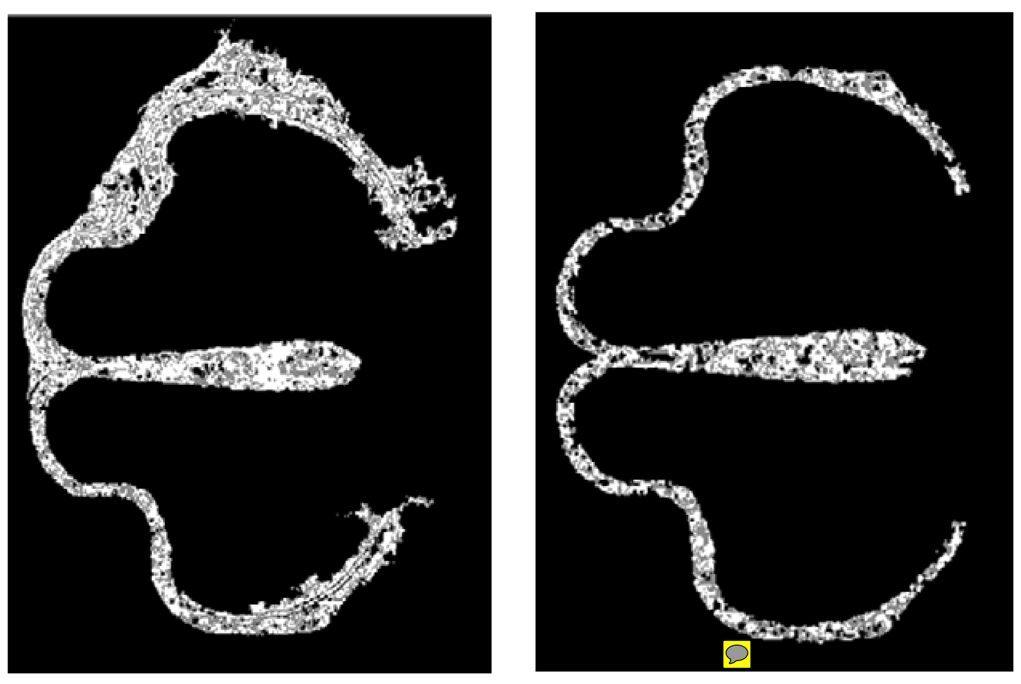
The principle of the region growing is to group pixels into a growing areas according to the selected criteria of homogeneity. In practice, it is used a static or dynamic criterion. This depends on the homogeneity of the segmented region. The dynamic criterion controls the homogeneity only of certain areas of the image and therefore is suitable for areas less homogenous. The region growing was implemented in 3D.

An algorithm for the region growing was developed in Matlab. The first step of the algorithm is the preprocessing of images which contain an olfactory system. In the next step there is displayed the middle of the pre-processed images and user chooses a certain number of initiation points. This points are used as inputs for the region growing and from them grow the segmented areas. Other pixels are added to the areas if they fulfil the homogeneity criterion. The resulting images are finally modified with suitable morphological operations..

Dynamic Criterion

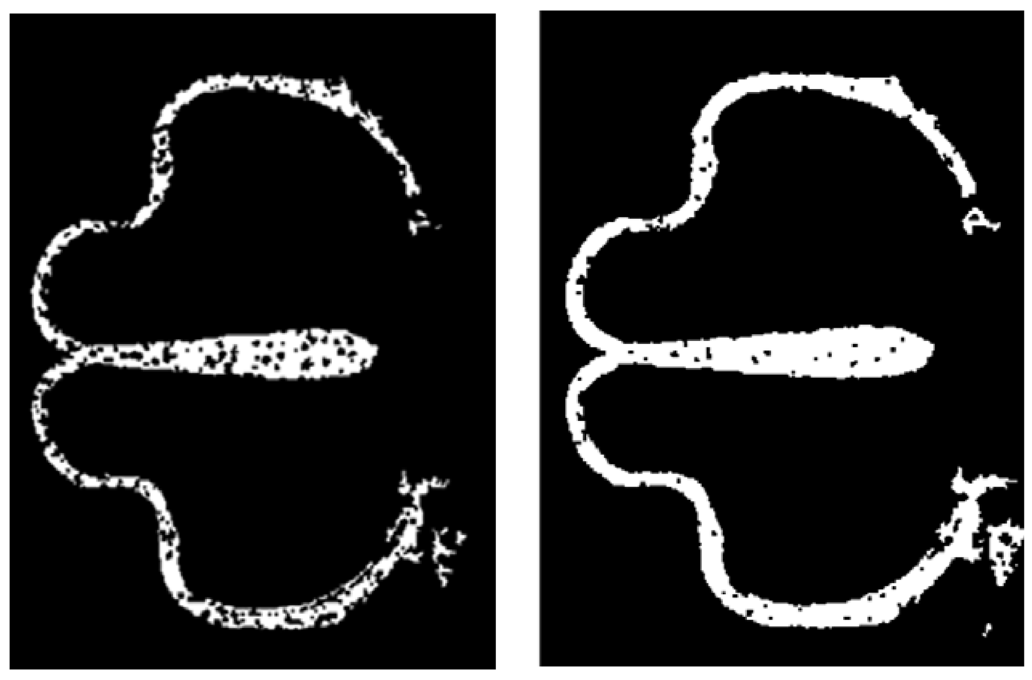
The dynamic criterion is calculated for a square or rectangular neighborhood of each pixel that was added to the segment, see the following equation.

$$p= \mu +- \sigma$$



Morphologic operations

The closing (morphological) operation was applied on the segmented region to remove small holes inside of the region, see the following figures.



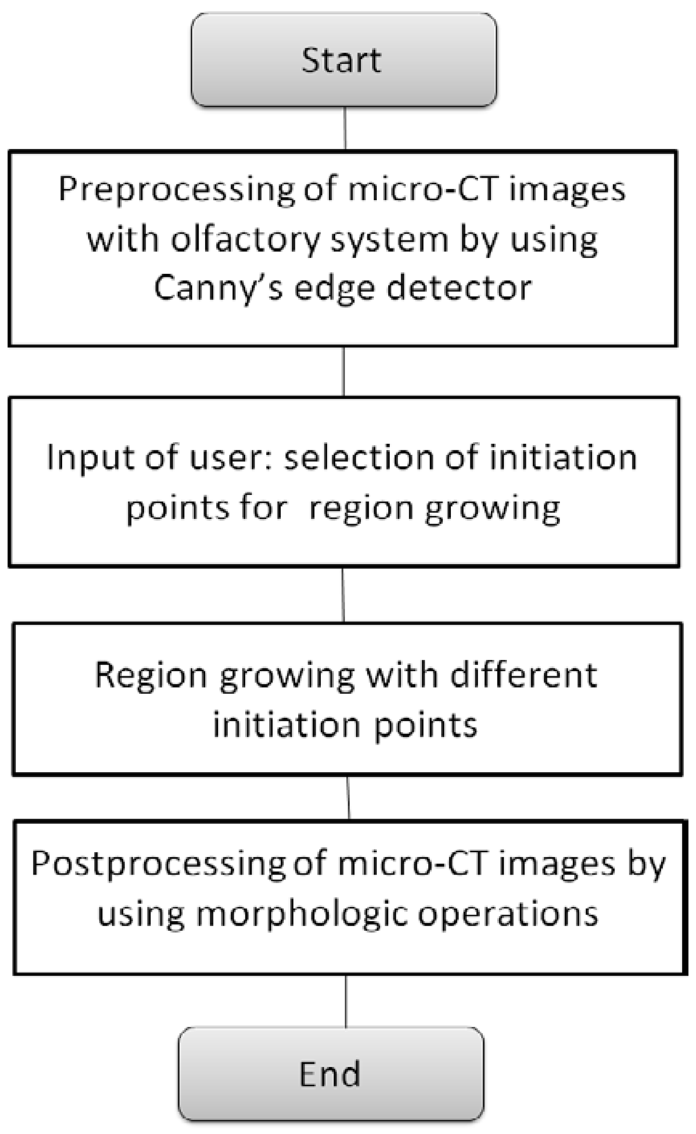
Large volume data

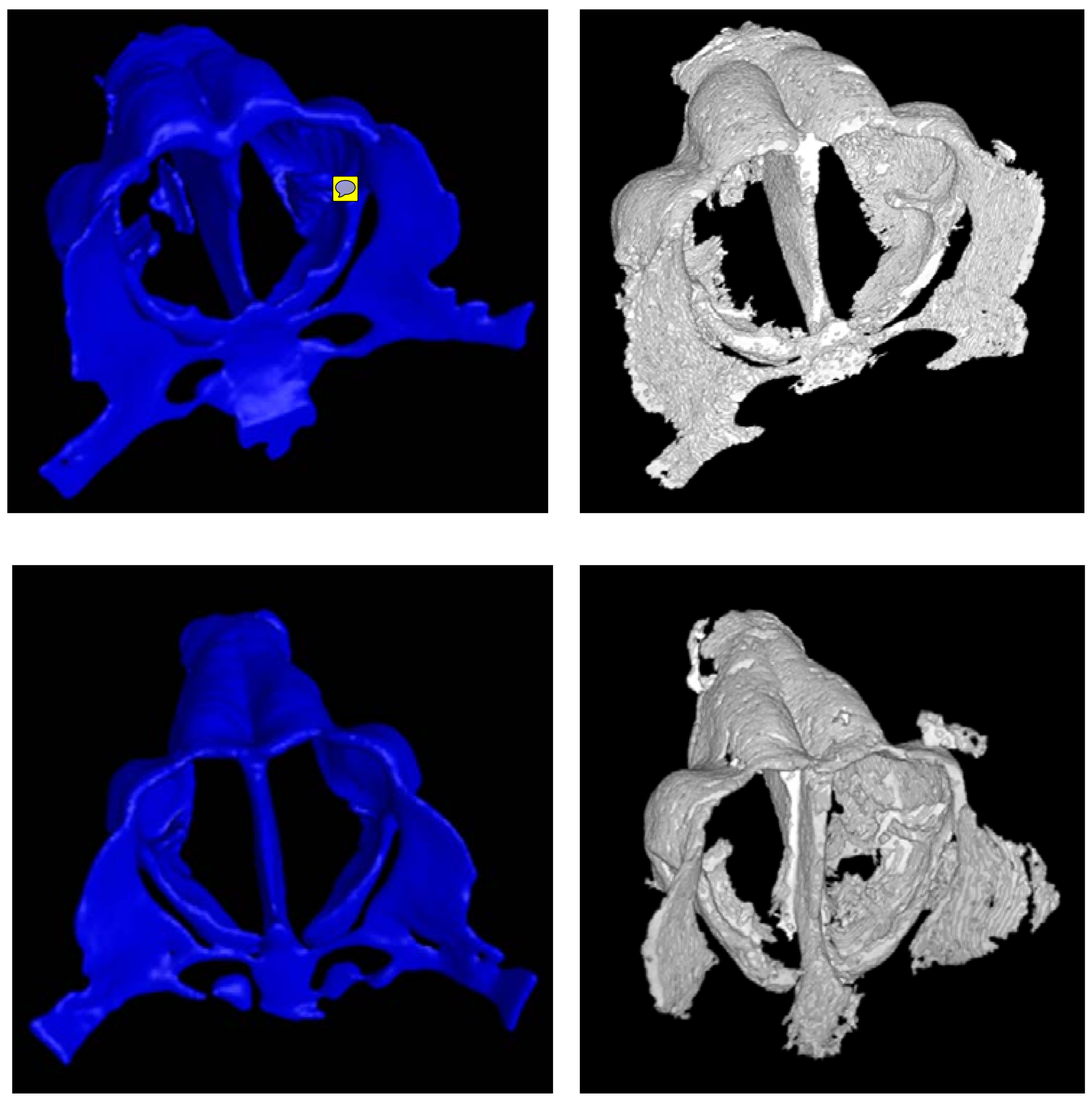
Algorithm generate big errors on the large volume data, therefore was applied on the partial data volume. It works automatically until the cartilage of olfactory system is gradually creates an entire olfactory system. The user chooses only the initiation points.

Summary

The following Figures of 3D models shows differences between manually and automatically segmented cartilage, at first mutated and non-mutated embryo. Manually segmented models are more accurate, but segmentation of one model took about 20 hours. Automatic segmentation took only about 2 hours...

Flow Diagram





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