

FROM MEDICAL IMAGE TO 3D ENTITIES CREATION

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ABSTRACT: *For the generation of a FE mesh, segmentation of 2D medical images is necessary. In this work, the two main regions of the Intervertebral Disc – i.e. the Nucleus Pulposus and the Annulus Fibrosus – were the structures taking in consideration for image segmentation. A set of different algorithms and filters were used, together with a commercial software, and its results presented and discussed.*

KEYWORDS: Segmentation, FE mesh generation, Intervertebral Disc

1. INTRODUCTION

In order to obtain a 3D entity, to be used in a Finite Element (FE) simulation bio model, a set of procedures needs to take place, been the most important the segmentation of the medical images. Segmentation can be defined as a process of voxelization of a 3D domain reconstructed from 2D images, identifying the different structures and tissues, for subsequent generation of a suitable FE mesh.

The aim of this study is to built up an automatic procedure for the segmentation of the Intervertebral Disc (IVD), taking into consideration its two main regions: the Nucleus Pulposus (NP) and the Annulus Fibrosus (AF), departing from micro-MRI medical imagery.

In this study, samples of goat's IVDs – provided by the STEGA - Skeletal Tissue Engineering Group, Vrije Universiteit Medical Center, Amsterdam, research partners in a broader project, and their subsequent image acquisition kindly obtained via the Department of Biomedical Engineering, Eindhoven University of Technology, both of The Netherlands – were used.

2. METHODOLOGY

A commercial software was used and the various algorithms, employed for the image

segmentation, will be described in detail in their application to the NP structure.

In Fig.1, a sagittal cross section of the IVD, the orange lines represent the first (top) and last (bottom) images. The green line identifies the slice used here, to exemplify the segmentation procedure.

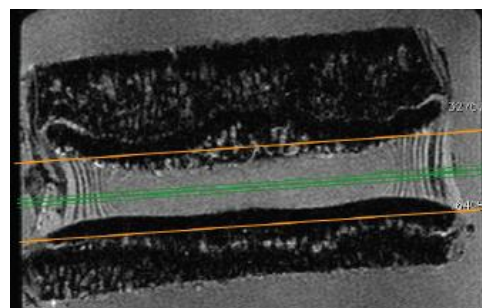


Fig. 1 - Slice location

Fig.2 shows the various images available to build up the 3D entities. In a total of 18, each transversal cross section has 0.5 mm of thickness, with an axial spacing of 0.6 mm between them, obtained with a Brunker BioSpin MRI equipment, at 400.2463702 MHz, a bandwidth of 256.9901316 pixes and post-processed with ParaVision and Dicom OFFIS DCMTK 354 mage converter software.

For the following exemplification of the segmentation procedure, image 13 of Fig.2 was used.

Fig.3 (a) represents the original image.

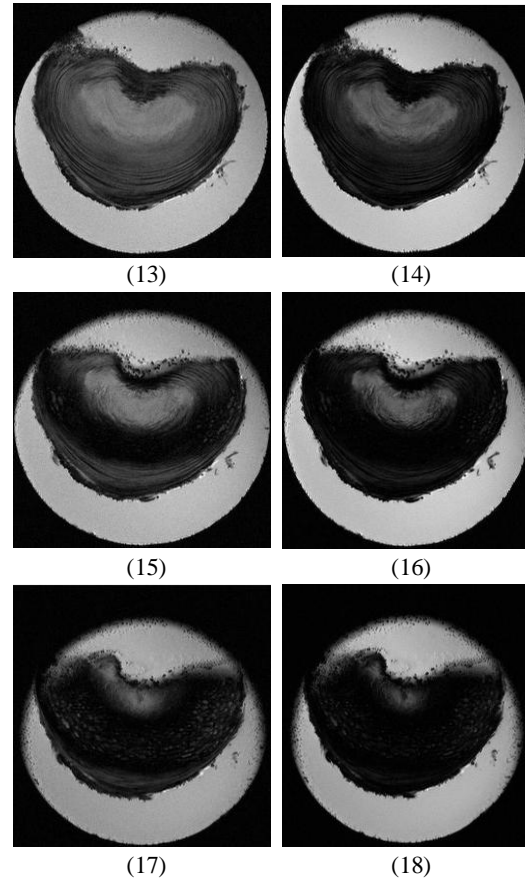
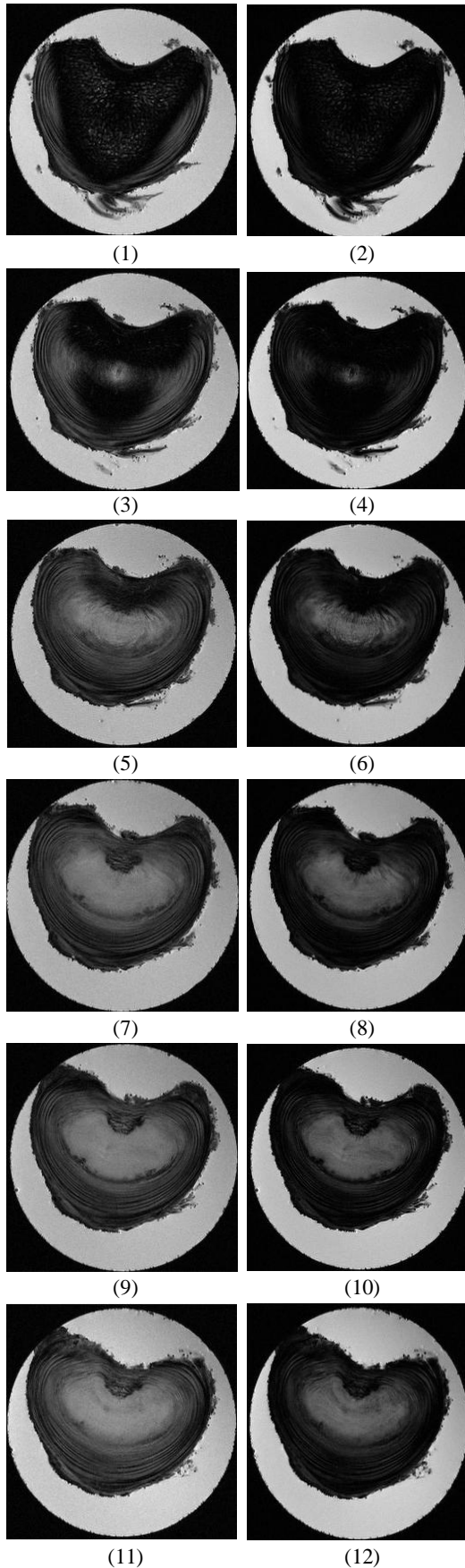


Fig. 2 - Original Images used for segmentation

2.1 Noise filtering - curvature anisotropic diffusion filter

This filter is intended to preserve edges, requiring three parameters: the number of iterations to be performed, the time step and the conductance parameter, used in the computation of the level set evolution.

Typical values are: no. of iterations = 5, time step = 0.25 and conductance = 2, for 2D images, and the results can be seen in Fig.3(b).

2.2 Confidence connected region growing

The algorithm involves the selection of seed points, which will control the formation of the regions into which the image will be segmented. It examines the neighbouring pixels of the initial seed point, determining whether the pixel neighbours shall be added to the region or not. This filter requires three parameters: number of iterations,

multiplier (i.e. the number of standard deviations, to include in the intensity model) and initial neighbourhood radius, this last representing the radius of the neighborhood over which intensity model is calculated.

This algorithm produces the results of Fig.3(c).

2.3 Smoothing - recursive Gaussian filter

Removing 'noise' and smoothing the image is achieved by applying a Gaussian kernel. The parameter involved is the Gaussian sigma, which refers to the standard deviation of the Gaussian kernel. The value of sigma controls the width of the Gaussian kernel, i.e. the larger the value of sigma the larger is the kernel support. In general, higher values of sigma tend to smooth the image, but its value must not be greater than the relative size of the objects under concern, otherwise the relevant features of the image may be lost.

The final result is displayed in Fig.3(d).

3. RESULTS AND DISCUSSION

The resolution of the original micro-MRI images was of 0.12x0.12x0.59 mm.

The segmentation sequence of the NP, by application of the different filters, can be fully followed in Fig.3:

- Fig.3(a) shows the original image.
- In Fig.3(b) the curvature anisotropic diffusion filter 'denoised' the image.
- In Fig.3(c) a confidence connected region growing segmentation algorithm was applied, where a seed point was selected and the correspondent region segmented.
- Finally, in Fig.3(d), a recursive Gaussian filter was applied, smoothening the all segment and highlighting a sound boundary outline.

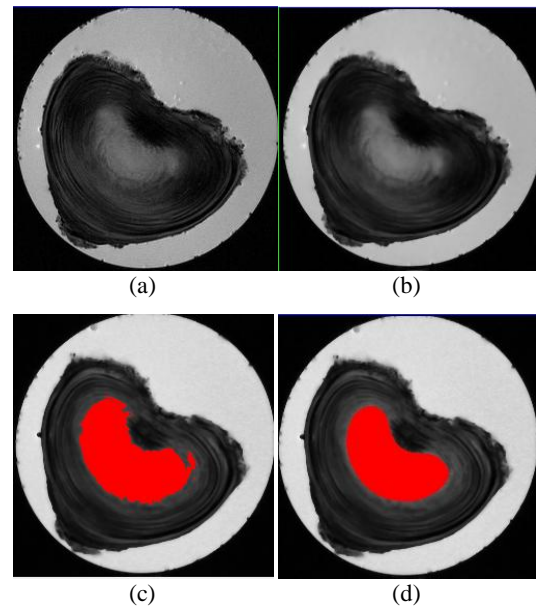
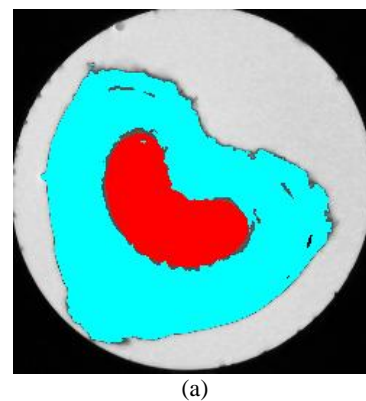


Fig. 3 - NP Image segmentation

- (a) original micro-MRI image
- (b) noise filtering: curvature anisotropic diffusion filter
- (c) confidence connected region growing
- (d) smoothing: recursive Gaussian filter

For the AF the same procedures were applied and results are shown in Fig.4 (a) and (b), although here only partially, due to the similarity of the process:

- In Fig.4(a) a confidence connected region growing segmentation algorithm was applied. A seed point was selected and the correspondence region determined.
- In Fig.4(b) represents the recursive Gaussian filter, smoothening the segmented image.



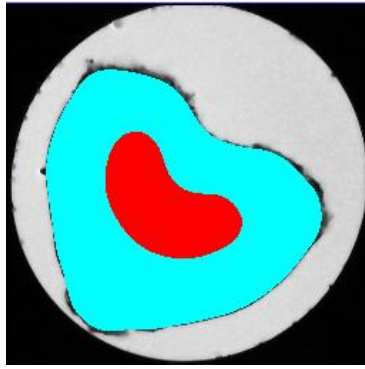


Fig. 4 - Image segmentation for AF
 (a) confidence connected region growing
 (b) smoothing: recursive Gaussian filter

With these results it is possible to draw a mask preview of the different structures, as seen in Fig.5.

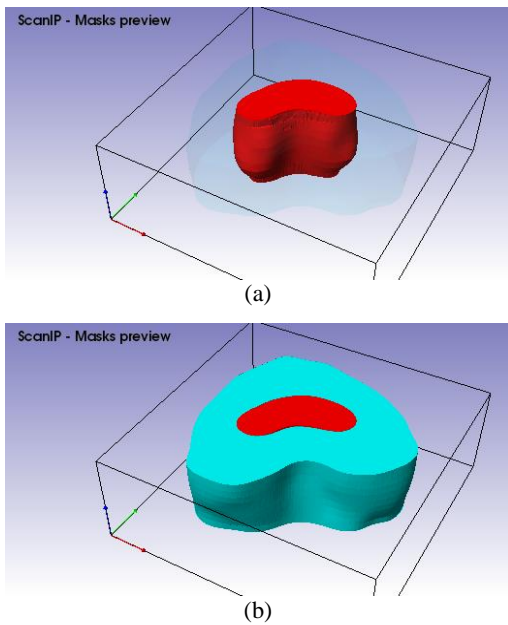


Fig. 5 - Mask preview
 (a) NP
 (b) NP and AF

Here, Fig.5(a) represents the mask preview for the NP, while Fig.5(b) is the mask preview for the all IVD (i.e. both the AF and NP assembly).

The geometrical accuracy of the FE mesh depends on the size of the grid dimensions. In this study a 0.25 mm grid size was used, and the various parameters employed in the above treatment are listed in Tab.1.

Table 1 – Values of the parameters employed in the FE mesh generation

Voxel dimension [mm]	0.117188	0.117188	0.593415
Voxel diagonal [mm]	0.62		
Grid size [mm]	0.25		
N	0.70		
σ_1 (0.5 x N)	0.35		
σ_2 (1 x N)	0.70		
σ_3 (2 x N)	1.41		
σ_4 (4 x N)	2.80		
σ_5 (6 x N)	4.20		

where N and σ are the two inputs for FE mesh generation:

- N is associated with the definition of the grid size and it is possible to determine its value as a function of the voxel diagonal, l, as seen in Eq.1.

$$N = \frac{\text{"Grid Size"} \times \sqrt{3}}{l} \quad (1)$$

- σ is used for sampling and defines the standard deviation of the Gaussian distribution. Therefore, σ is used for smoothing the image.

If σ is too high, the boundaries are smoother and loss of anatomical geometrical definition can occur. If σ is too low, less smoothing occurs and the discrete voxel structure is wrongly captured [1].

After analysis and selection of the parameters' values, the FE final entities mesh is shown in Fig.6 and 7.

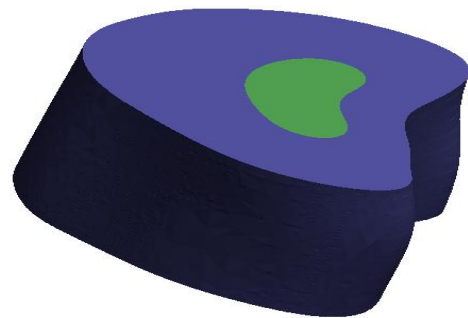


Fig. 6 - FE mesh obtained for N=0.7 and $\sigma = 4.2$



Fig. 7 - Sagittal cross section of the obtained FE mesh

4. CONCLUSIONS

In this study, an automatic segmentation was possible thanks to the good image resolution and contrast between structures. The resolution of medical images, i.e., pixel size and spacing between slices, plays a critical role on the accuracy of generated 3D geometrical models.

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REFERENCES

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