ON THE EFFECT OF VASCULAR TREE PARAMETERS ON 3D TEXTURE OF ITS IMAGES

M. Kocinski[1], A. Materka[1], and A. Lundervold[2]
[1]Institute of Electronics, Technical University of Lodz, Lodz, Poland, [2]Department of Biomedicine, University of Bergen, Bergen, Norway

INTRODUCTION

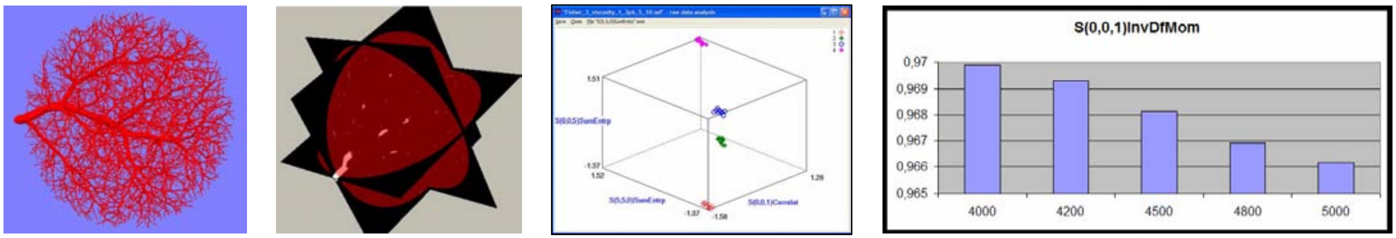
Quantitative information extracted from magnetic resonance images (MRI) of blood-vessel trees can be of significant value to medical diagnosis of vascular system diseases. Due to limitation of MR scanners, only the vessels thicker than voxel size can be clearly visualized. Thinner vessels create macroscopic patterns in MRI – regions of characteristic texture [1]. The proposed method for quantitative description of blood-vessel tress is to use texture analysis [1] for blood vessel trees classification and/or their parameters indirect monitoring. The aim is to demonstrate that there exists correlation between the physical parameters of a blood-vessel tree and numerical texture parameters computed from the tree images.

MATERIALS AND METHODS

The computer-simulated vascular trees were used in the described study. The process of vascular tree growth, based on physical laws and physiological assumptions is described in literature [2]. Representative trees of few classes of different properties were generated. The variable parameters investigated were number of output branches (4000-5000), input blood flow (0.5 – 0.625 l/min) and blood viscosity (1 – 10 cP). A simple simulator was used to convert the vector-described vascular trees into their 3D raster images. The simulated brightness of each voxel was approximately proportional to the volume of the voxel part occupied by a vessel crossing it [3]. Texture analysis of the resulted images was then performed through texture features extraction with the use of Haralick's [4] co-occurence matrix extended to 3D [5], inside a preselected volume of interest (VOI). Texture feature vectors were subsequently classified to reflect the vascular tree properties.

RESULTS

An example of vascular tree is shown in Fig. 1a, along with its transformation into 3D raster image (Fig. 1b). Each tree was fully contained in a cube 60 mm a side, divided into 8 million voxels (with side equal to 0.3 mm), each of them comprising 3^3=27 regularly spaced control points used to evaluate image brightness. The radii of simulated trees varied in the range from 0.03mm to 1.3mm. To compute texture parameters a circular and spherical ROI were used for 2D and 3D images, respectively. For 2D texture of images simulated for 3 classes of trees (N=4000, 4500, 5000), a 1-NN classifier failed in 17 out of 30 cases whereas none of thirty 3D images was wrongly classified. In another experiment, for constant number of terminal branches and the input flow (4000, 0.5 l/min), blood viscosity was varied from 1 to 10. Such defined vessel tree classes are also very well separated in 3D texture feature space (Fig. 1c) – the Fisher coefficient exceeded the value of 1000. A monotonous relationship between the mean values of 3D texture parameters and the physical tree parameters was also observed in the pooled data set (Fig. 1d).



(a) (b) (c) (d)

Figure 1. Generated vascular tree with 4000 terminal branches (a). Simulated 3D image of vascular tree (b) with a spherical VOI colored in red. Scatter plots in 3D texture feature space for 4 classes of simulated vascular trees with 4 different blood viscosity values (c). Example relationship between mean value of co-occurrence matrix 3D texture feature [(0,0,1) inverse difference moment] and the number N of terminal branches of the tree.

CONCLUSIONS

Numerical simulations show that there exists a correlation between the texture parameters of MR-like images of blood vessels trees and physical parameters of the trees. Two-dimensional analysis does not reveal these relationships – 3D texture analysis is necessary. Approximate image simulation, with 28 intensity levels was sufficient to obtain the results, that was confirmed by studying the effect of image intensity additive noise on image texture classification. Texture analysis can be used to increase the amount of quantitative information beyond this obtainable from vessel segmentation in MRA images.

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