3D VISUALIZATION OF THE SPLEEN FROM MRI SEQUENCES

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Abstract

The modern medical imaging is using more often 3D volume visualization of organs for better observation of the anatomical structure and medical diagnostic. This paper proposes an algorithm for 3D visualization of a segmented human spleen, extracted from a sequence of MRI-images. Such visualization is a logical processing step in a depth comprehensive processing of a sequence of medical images which is preceded of preprocessing and segmentation of anatomical structures.

1. INTRODUCTION

The form of the human spleen is very variable by the different individuals. So the visualization of this organ is very interesting and helpful by studying its shape, functionality and disorders. The spleen has the same relationship to the circulatory system that the lymph nodes have to the lymphatic system [1]. A wide range of diseases can affect the spleen. MR imaging is an excellent tool for diagnosis and evaluation of focal lesions and pathologic conditions of the spleen. Also for studies of health, because of the harmless magnetic field that is used by MRI.

To be visualized the spleen has to be segmented first. There are a lot of segmentation techniques, but not all of them are giving good results in the different cases. Because of the partial volume effect, the gray level of the spleen and grayscale similarity of the adjacent abdominal fat, spleen segmentation has always been a problem [2]. In this case an active contour method for segmentation has been chosen. The "Active Contours Without Edges" by Chan and Vese, that ignores edges completely [3], has been studied in previous work [4, 5] and has shown very good results by the spleen segmentation from abdominal MRI images. After segmenting the spleen from all of the images in a MRI-sequence is used a 3D volume visualisation, that is based on isosurfaces. An Isosurrace can be described as a level set of a continuous function in a 3D-space domain. It is a surface that represents points of a constant value within a volume of space [6]. Before the segmentation and 3D Visualization we can use different filtration and morphological operation if the image data requires it.

2. 3D VISUALIZATION USING ISOSURFACES

An Isosurface can represent Voxels in various types of medical images with Colocalization level. Those points can be joined to form a 3D surface. As all methods and techniques the Isosurface has its own specific calculation method. The 3D dataset is first thresholded at a certain level. The isosurface is the surface that envelops the remaining voxels. The marching cubes algorithm was first published in the 1987 SIGGRAPH proceedings by Lorensen and Cline [6], and it creates a surface by intersecting the edges of a data volume grid with the volume contour. Where the surface intersects the edge the algorithm creates a vertex. The algorithm creates a surface by using table of different triangles, which depends on different patterns of edge intersections. In the modern image processing there are already upgraded Isosurface algorithms such as Scalar Algorithms [8], Surface Nets, Dual Contouring and Isosurfaces and Level-sets [9].

2.1. Scalar field Visualization: Isosurface

Scalars are single data values associated with each point and/or cell of a dataset [10]. Because scalar data is commonly found in real-world application also in MRI images, many different visualization algorithms exists: e.g. Color Mapping, Contouring, Scalar Generation. Color mapping that is used also in the proposed approach in this paper is a common scalar visualization technique. It maps scalar data to colors and displays the colors using standard implemented facilities of the graphic libraries. For this purpose color lookup table is often used. According the table the scalars s_i have minimum and

maximum range into which the scalar values are mapped.

$$s_i < min, k = 0$$
$$s_i > max, k = n - 1 \qquad (1)$$
$$k = n \frac{s_{i-min}}{max - min}$$

In the case in this paper the choice of the look up table is not so hard, because we have an already segmented structure that should be in one colour. Other colours are used by representing different sections of the organ to distinguish the outer structure from the inner.

3. ALGORITHM FOR 3D VISUALIZATION OF THE SPLEEN

The algorithm of the approach is presented in the Block diagram, shown in Fig. 1.

The first step is to load a sequence from abdominal MRI – images. In the pre-processing step a Homomorphic-Wavelet Filtration is applied to the images that represent the spleen. The filtration method is chosen, because of the best SNR-results for MRI-images that it showed in a previous study [11].
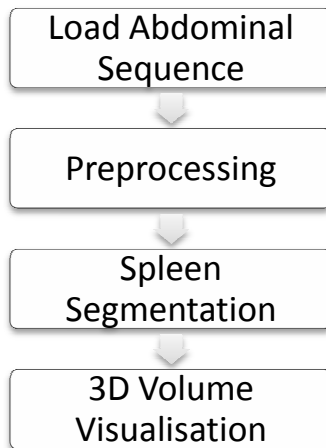
Load Abdominal Sequence

Preprocessing

Spleen Segmentation

3D Volume Visualisation

Figure 1. Flowchart of the main algorithm for 3D visualization of the spleen

The filtration is needed for reaching better results in the next segmentation step. The method of active contours without edges combined with level sets is giving the desired accurate binary segments from the MRI-images (Table 1).

Table 1: Experimental quantitative results: average Dice similarity coefficient and Implementation time for each tested method [5]

Segmentation method	Dice similarity difference (%)	Time (s)
Active Contour Without Edges	95.14	22.428
Active Contour With Edges	93.99	23.846
Region Growing	78.65	7.152

Another reason for using it as segmentation method in this approach is that the method is semi-automated and shortens the time for this part of the processing.

The last stage is the Volume Visualization, which includes:

— Building an array from the obtained segmented images;

— Removing singleton dimensions from the array;

— Color mapping the images from the array;

— Drawing the contours of the binary segments in volume slice planes;

— Drawing a patch of extracted isosurface data from volume data;

— Computing normals of isosurface vertices;

— Computing isosurface end-cap geometry;

— Setting face and edge colors;

— Specifying the view;

— Adding lights.

4. EXPERIMENTS AND VISUALIZATION

Many experiments have been conducted for evaluating the effectiveness of the proposed approach. The input image data includes 10 sequences of abdominal MRI-images from a study of health in Pomerania (East Germany). The sequences consist of 64 MRI-images each. They are in DICOM format with size 256 x 176 pixels and are in greyscale. The images from the study are representing no internal diseases or tumors. The volunteers are clinically healthy. The pathological indications were removed from the data base. Other specification of these images is that there quality is not as high as by

regular MRI examinations, because the time for the examination was shorter according to the purposes of the study. The experiments for spleen segmentation are made by computer simulation in MATLAB R2013 environment by using of IMAGE PROCESSING TOOLBOXES. In this paper are presented the obtained results by processing of one of the sequences. In this sequence the spleen were visible in 23 of all of the images (Fig.2).
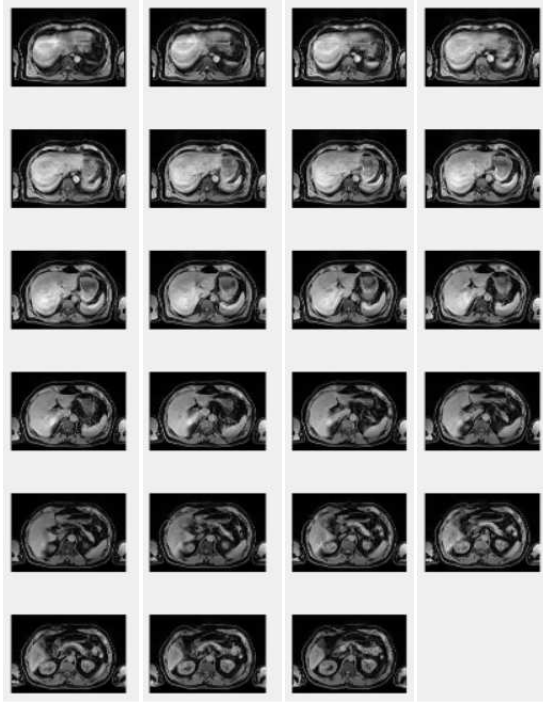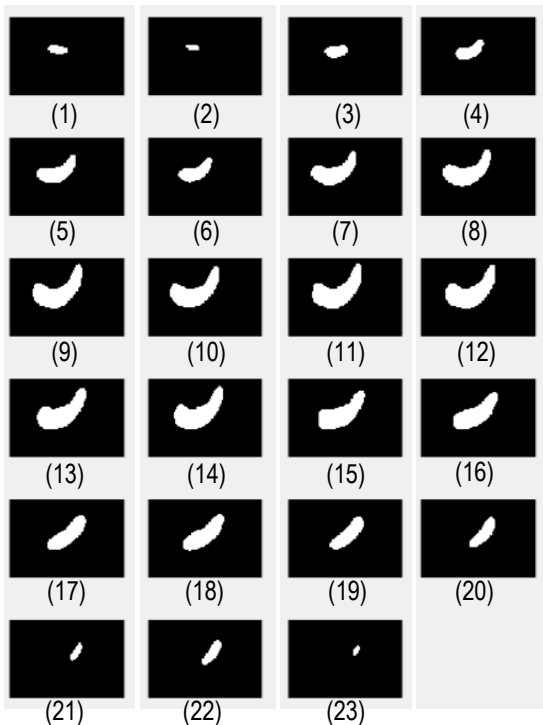

Figure 2. Sequence of 23 original images visualizing the Spleen

Figure 3. Sequence of the segmented spleen using active contours without edges

The obtained images after segmentation with active contours without edges are shown in Fig. 3. It is used a new method based on active countours that process the images from the sequence automatically. The mean Dice similarity index for the whole sequence is 78.7%. The curve on Fig.4 is representing the variance of the Dice coefficient from the first to the last image in the sequence. The coefficient for the images in the middle of the sequence, where the spleen is bigger, are very high (over 90% for images number: $8 \div 18$).
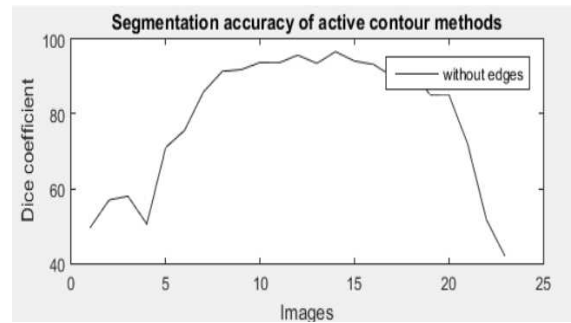

Figure 4. Variance of Dice coefficient for spleen segmentation from sequence of abdominal MRI images

On Fig. 5 are represented different stages from the 3D Volume Visualization method: Color mapping; Drawing contours of one segment; Drawing contours of several segments (layers) in volume slice plane.
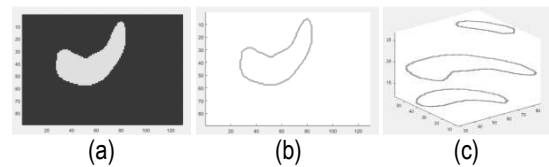

Figure 5. Image (a) is segmented spleen from image number: 9 on Fig.3 with colour map "parula"; (b) represents the contour of the segment and (c) is showing three contours of three different segments from images number: 7, 9 and 19 on Fig.3, but in volume slice plane

The final 3D Volume visualization of the whole spleen is on Fig. 6.

On Fig. 7 is a 3D visualization of the spleen from the same sequence, but segmented manually by hand. Although the relatively high Dice similarity index for the previously used segmentation method, it is obvious in the comparison between the two 3D visualizations that some part of the spleen segmented with the method based on Active contours is missing. So the 3D Visualization method could be very useful by evaluating of the accuracy of segmentation methods applied on image sequences.
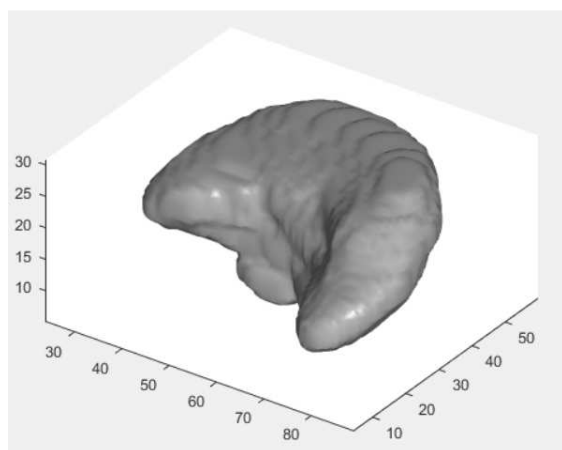
Figure 6. 3D volume visualization of the spleen segmented semi-automatically
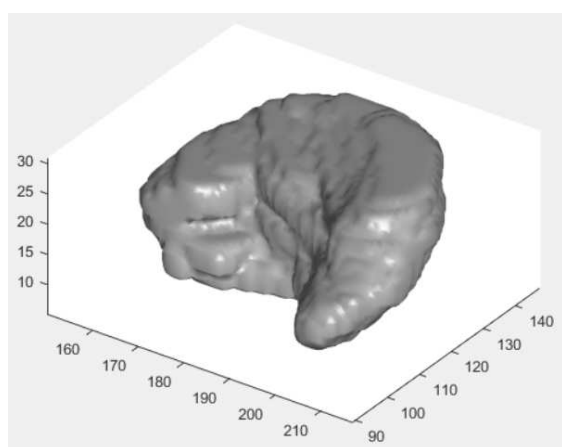

Figure 7. 3D volume visualization of the spleen segmented manually

5. CONCLUSION

The proposed approach for 3D Visualisation of the spleen has shown many applications in the analysis of abdominal MRI images. The conducted experiments enlarged these applications, by showing the capabilities of evaluating the accuracy of different spleen segmentation methods.

6. ACKNOWLEDGMENTS

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