Image Segmentation 3D Segmentation
Fuzzy c-Means, Live-Wire, Slices

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FUZZY 3D EXTENSION OF THE LIVE-WIRE APPROACH TO MEDICAL IMAGE SEGMENTATION

This paper concerns 3D segmentation problem. Proposed algorithm is an extension of 2D segmentation method, called Live-Wire, and operates on serial images, which are produced by the set of parallel images. Presented generalization is based on a fuzzy representation of the image and mathematical morphologic operations for binary images. Since the problem of extending Live-Wire method is popular in literature, related work will be discussed in the first order. Then the idea of initial Live-Wire algorithm will be presented. Finally, proposed algorithm will be characterized and obtained results will be introduced. This method was tested and optimized on the basis of medical images from MRI (Magnetic Resonance Imaging) and CT (X-Ray Computed Tomography) examination.

1. INTRODUCTION

Segmentation is an important step in an image analysis. It extracts a structure of a certain level of homogeneity. In medical images, like MRI and CT, these are anatomical or pathological structures. Moreover these models try acquire series of images that consist of a set of parallel slices. This lead to a 3D analysis, particularly 3D segmentation, which permits for a 3D visualization and measurement of various structures. Spatial presentation of anatomical structures can be helpful in medical diagnostic and treatment. Unfortunately, majority of current 3D segmentation methods require a burdensome user interaction, which makes the process time consuming, yet it allows the user to point the structure to be segmented. In this study a 3D image segmentation method has been developed. It refers to the Live-Wire approach for a 2D contour delineation employs the FCM (Fuzzy c-Means) clustering and the operation of mathematical morphologic for the extraction of the 3D objects.

Several extensions of the Live-Wire approach to 3D images (data volumes) have been addressed in the literature [1-4,7,6]. Unfortunately, none of the suggestions satisfies the user in terms of interactions and accuracy. One group of the segmentation methods [1,3,7] requires contours determination with user interaction on more than one slice (in the best case on two border slices). It is time consuming in exchange for the relatively high precision. Others methods [2,6] are

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based on interpolation. In the first place, on the selected slice, a contour detection of the segmented structure requires a user interaction. Then, some contour points, market by the user, are mapped on to the neighbour slices. This process is performed automatically by searching the maximum value of image gradient in the neighbour area of the analyzed points. Next, the transferred points at each slice are connected based on the 2D approach principles. In the current study an extension method has been developed, which maps the contour to neighbour slices without a user interaction.

2. LIVE-WIRE APPROACH

A 2D Live-Wire approach [5,8-10,12] is based on analysis of image boundaries and consist of several stages. First computation of the image cost map is required. It reflects the edge properties in each image pixel. Then, the image is represented by a graph, in which each vertex corresponds to a pixel of image and edges link vertex with each of its eight neighbouring vertices. Each vertex refers to an element of the image cost map. Next optimal paths are found in a graph. To choose the desired edge, a user specifies characteristic points, namely seed point and free point. By repeating performing the operation the segmentation of the given structure is made. A closed contour stops the segmented structure, as a final result. The contour is ready for being extended to neighbour slices.

3. THREE-DIMENSIONAL SEGMENTATION

The Live-Wire method extracts the contour on one slice. The goal of the next phase is to extend the contour information and delineate the structure border in three-dimensional space.

In one step two neighbour slices are processed. The first slice with the already located edge is referred to as a reference slice I_r. The processed slice is called the destination slice I_a. The contour is propagated in both directions (Fig. 1). It stops when no more segmented structure is shown on slice.

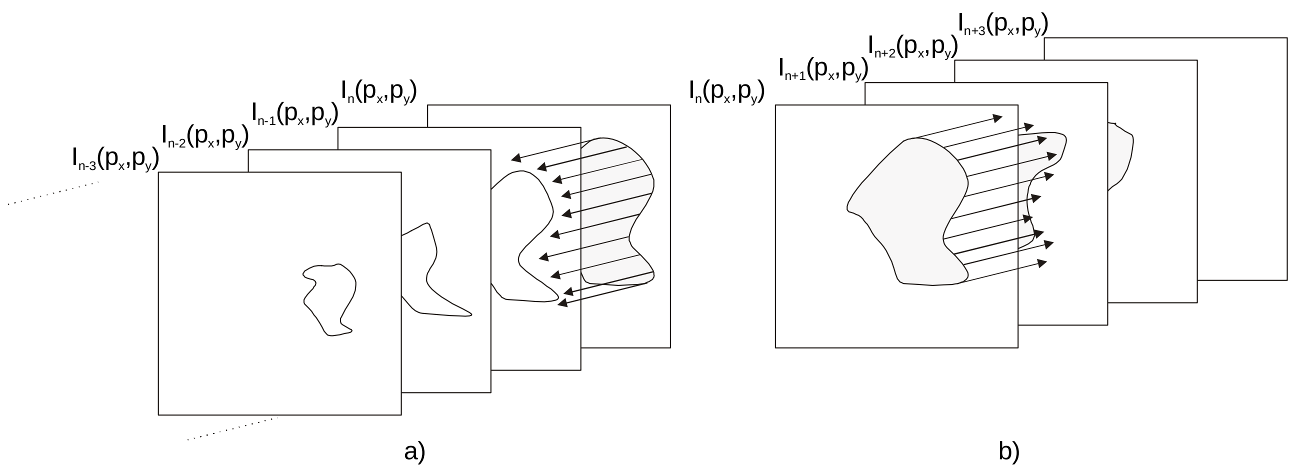

Fig.1. Propagation of information about contour of segmented structure between neighbouring slices, (a) direction of decreasing number of images, (b) direction of increasing number of images.

3.1. NEIGHBOURING SLICES ANALYSIS

The analysis applied to neighbour slices starts with a FCM algorithm and after binarization, mathematical morphologic operations are implemented. The algorithm can be presented in several steps:

STEP 1: Clustering pixels belonging to I_r, I_a slices by means of the FCM algorithm. Required number of classes for a certain type of study is selected empirically. This step results with two images: I_r^{FCM} I_a^{FCM}, whose grey level value corresponds to cluster centers.

STEP 2: Pixels of the reference slice I_r, belonging to the segmented structure are set to 1, i. e.:

$$I_r^B(\overline{p}) = \begin{cases} 1, & \overline{p} \in S \\ 0, & \overline{p} \notin S \end{cases} \tag{1}$$

where $\overline{p}$ denotes the vector of pixel and S denotes the segmented structure.

STEP 3: The most numerous FCM class v_S determination, based on reference slice.

STEP 4: Pixels of the destination slice I_a, which belong to the v_S class are set to 1, i. e.:

$$I_a^B(\overline{p}) = \begin{cases} 1, & I_a^{FCM}(\overline{p}) = v_S \\ 0, & I_a^{FCM}(\overline{p}) \neq v_S \end{cases} \tag{2}$$

STEP 5: Determination of the common part of high level regions of both slices I_r^B, I_a^B:

$$I_{r,a}^B = I_r^B \cap I_a^B \tag{3}$$

STEP 6: Morphological reconstruction of the binary image, with filling the holes and smoothing boundaries.

STEP 7: Contour detection of the segmented structure.

As a result, the closed contour of the segmented structure on the destination slice I_a is obtained. In the next iteration of 3D segmentation the destination slice becomes the reference slice I_r, as shown in Fig. 1.

4. RESULTS

The algorithm has been tested on clinical CT and MR images. In this paper only CT chest examination are presented. Both lungs have been submitted to segmentation process. Since a single study contains 35, 70 or 140 images, in Fig. 2 only selected slices are shown.

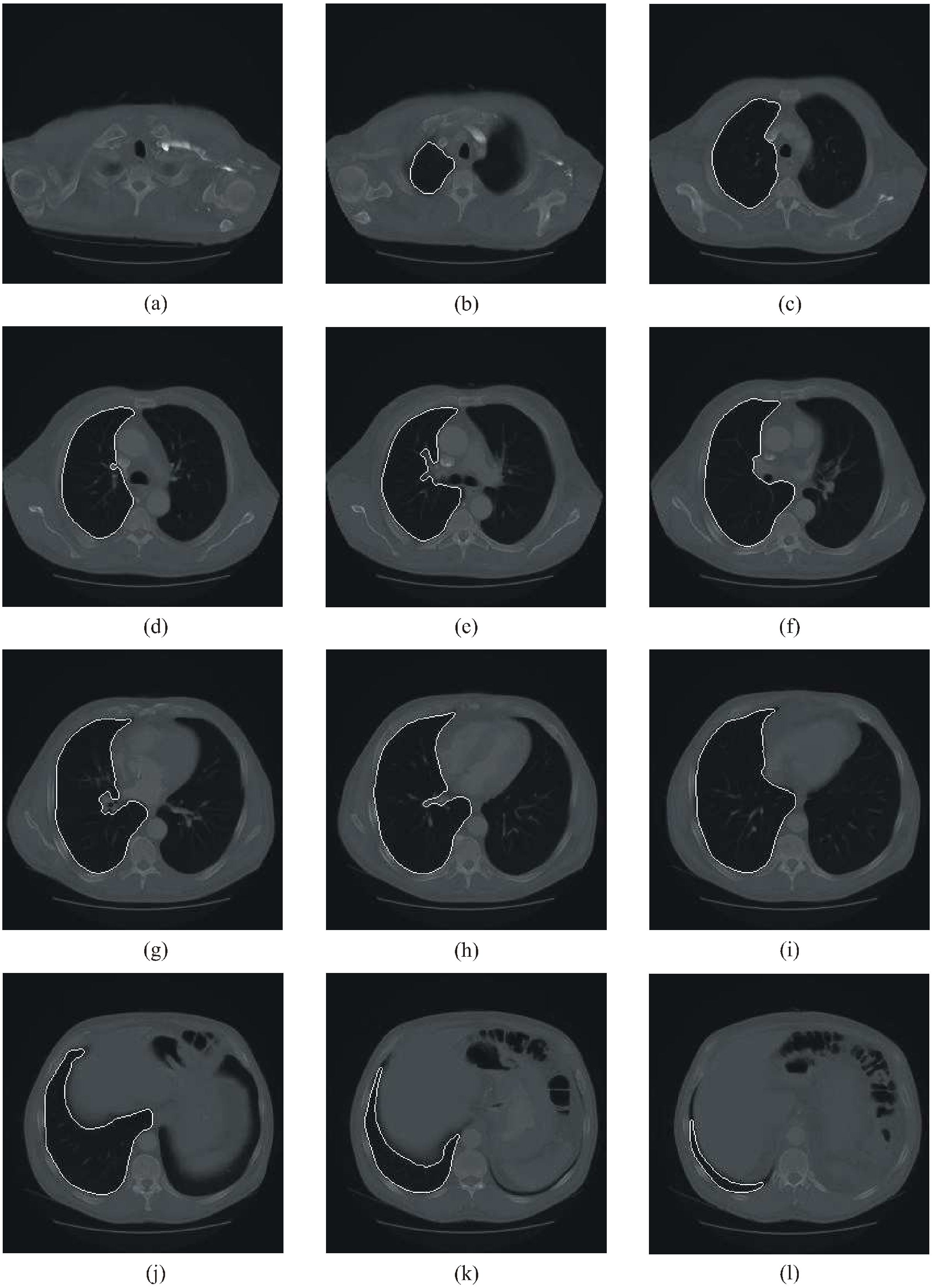

Fig. 2. A 3D segmentation of the single lung from serial images of chest CT examination, (c) contour obtained by Live-Wire algorithm, (b),(d)-(l) contours obtained by 3D extension of Live-Wire method

On a single slice (Fig. 2c) the contour has been extracted by Live-Wire method. All other slices present a 3D extension algorithm. If the segmented structure is not shown on a slice (Fig. 2a) the analysis stops.

The structure can also be displayed in a three-dimensional space. At this phase the Visualization Toolkit [8] has been implemented. The results are shown in Fig. 3.

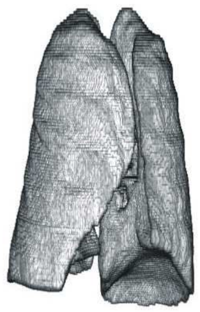

Fig. 3. A 3D visualization of both lungs

This method was also tested in terms of noise resistance. Two different noise models were utilized: Gaussian and impulse noise with various parameters. Noise participation was described by signal to noise ratio defined as:

$$SNR = 10 \cdot \log_{10} \frac{\sum_{\bar{p}} I'(\bar{p})^2}{\sum_{\bar{p}} [I(\bar{p}) - I'(\bar{p})]^2} \tag{4}$$

where $I(\bar{p})$ denotes the reference image (without noise) and $I'(\bar{p})$ denotes the noisy image connected with the reference image. To estimate noise resistance various measures were used (i.e. Figure of Merit, the size of area). Correct segmentation was possible even if signal to noise ratio were equal to some dB. Morphological operations which were used in proposed algorithm gave it strong independence from the noise.

5. CONCLUSION

The goal of this study is the problem of 3D segmentation from serial images, which are constituted by the set of parallel images. Proposed algorithm of 3D segmentation is completely automatic, requires only semi-automatic 2D segmentation at a single slice. With this end in view Live-Wire algorithm is suggested.

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