A Level Set Based Method for Lung Segmentation in CT Images

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Abstract—**In this paper an automatic computer-aided (CAD) method is utilized for lung segmentation using computed tomography (CT) images. We segmented lung regions - based on the CT data- with nodules attached to the chest wall by using level set modeling. This method is made up of 3 steps: In the first step, an adaptive fuzzy thresholding operation is used to binarize the CT images; in the second step, the lung with non-isolated nodules is segmented applying both level set modeling and convex hull algorithm. In the third step, by using the shape features of lung lobe, the lung is segmented. The experimental results show an accuracy of 98% by our method with out performance other exiting methods.**

Keywords—lung; segmentation; level set; convex hull

I. Introduction

Today, lung cancer, amongst other types of cancer, is the number one killer in men and the second leading cause of death in women around the world [1].Unfortunately, since no symptom appears early on, lung cancer is diagnosed late. The large number of CT images coupled with huge amount of data indicates the need to designing a full automatic system by machine vision specialists. Pulmonary nodules are detected and diagnosed through several steps in a CAD system. Textures such as nodules and bronchis can be found in the lung space which closely resemble the walls of the lungs in terms of intensity and their occasional attachment to the chest wall makes diagnosis difficult [2].To detect lung nodules, primarily the lung and non-lung regions must be segmented. Then, the nodule detection algorithms are used only for the lungs which can accelerate the nodule detection process with more accuracy. Fig. 1 demonstrates CT images of a lung with two nodules attached to the chest walls.

In recent years, several methods have been adopted for segmentation of the lungs which are categorized in two general groups. The first group is based on the intensity of the image using threshold and some morphological operators [3, 4]. The second group focuses on ACM [5, 6].

A. Previous Methods

Ye et al. [3] presented a three-dimensional adaptive threshold method for the segmentation of primary lung mask.

Fig. 1. Lung CT image with nodules attached to the chest wall

The binary image was considered as the primary lung mask. For solving this problem the Chain Code method was used in order to smoothen the lung border, filling of the troughs and as a result segmentation of nodules into the lung space [7]. However, this method is not efficient for larger nodules. This method, obtained an overall detection rate of 90.2% and FP scan value of 8.2/scan.

Lai and Ye [6] for the first time discussed the issue of segmentation of nodules attached to the wall while discussing lung segmentation. In this method the initial contour is considered as a large ellipse around the lung, and the active contour with control over shape was moved to the lung border. In this way, an initial shape was considered for the moving active contour. Due to this, even in images of the lung, with nodules attached to its walls, the contour does not cross the initial shape that was intended for it and is fixed to the actual border of the lung. The first problem faced in this method is that some of the chest wall as part of lung space has been segmented. The second problem is the time consuming algorithms.

Shimoyama et al. [5] presented an article about the automatic detection of nodules attached to the wall. In this method an active contour has been used for the segmentation of lung. An important initiative that was applied in this paper was that the final contour of each slice was used as the initial contour of the bottom or upper slice. The initial slice was selected manually from among slices which had no nodules

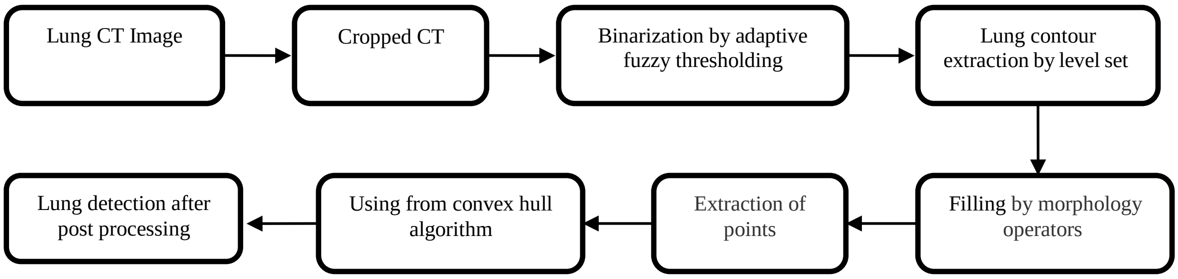


Fig. 2. Block diagram of the proposed method.

attached to the wall. Then the final contour of the initial slice was used as the initial contour of the next slice [8]. The method proposed in this paper, due to the manually selected initial slice, is not fully automatic as it claims to be. Another disadvantage of this method is that it does not function properly on data that has slices thicker than 2mm. This is because in these conditions the adjacent slices are far from each other and thus have little similarity. Therefore the final contour of a slice is not a suitable initial contour for the adjacent slices. Thus, the number of true positives was increased from 7 to 10.

B. Our Approach

This paper presents a new algorithm for segmentation of lung with nodules attached to lung wall in CT images. In terms of its intensity the nodule texture is very similar to lung wall. For this purpose, after the binary image of the lung, the accurate lung border is determined using the tool level set. Then, a convex hull algorithm is used for segmentation of nodules attach to the wall of the lung, and finally process of the lung segmentation is completed using a post-processing step.

This paper is organized as follows: The proposed method is presented in section2 then, section 3 discusses the results of lung segmentation by level set, and finally conclusions are presented in section 4.

II. PROPOSED ALGORITHM

In order to detect all the nodules available in the lung region a useful algorithm for lung segmentation is needed. In some of the data, the nodules attached to the chest wall make the process of lung segmentation difficult. In this section, the proposed methods for lung segmentation are accompanied by solutions for the large and small nodules attached to the wall. The proposed method is introduced by using binary of image and level set model and also using the convex hull algorithm. An overview of our proposed algorithm is given in Fig. 2.

A. Image Pre-Processing

In the first step, the lung CT scan image is automatically cropped due to the existence of sections that do not have any role in lung segmentation. The results of this stage are shown in Fig. 3 (b) for a slice of CT data of a patient.

In the next stage, the lung binary image is produced by an adaptive fuzzy thresholding method [9]. Most of the lung space pixels have lesser illumination intensity than the walls. For this reason, after the binarization image, the lung space is zeroed and the wall is set to one. At this stage $T_{high}(i)$ and $M_{high}(i)$, are simultaneously defined as the cumulative histogram and the first moment of maximum intensity, $I_{\max}$. Similarly $T_{low}(i)$ and $M_{low}(i)$ are defined as starting from the minimum intensity $I_{\min}$. The minimum and maximum intensity of the image I is calculated. Therefore $M_{high}(i)$ and $M_{low}(i)$ are calculated according to the following equation [10]:

$$M_{high}(i) = \sum_{k=i}^{I_{\max}-1} k \times p(k) \qquad 0 \le i \le I_{\max} - 1 \qquad (1)$$

$$M_{low}(i) = \sum_{k=0}^{i} k \times p(k) \qquad 0 \le i \le I_{\max} - 1 \qquad (2)$$

In this equation $p(k)$ is the level of histogram of intensity level in *k* and *i*, is the desired intensity level. The amount of *I* divides histogram into two sections. The average for these two sections is calculated through the following 3 equation:

$$\mu_{high}(i) = \frac{M_{high}(i)}{T_{high}(i)} \quad , \quad \mu_{low}(i) = \frac{M_{low}(i)}{T_{low}(i)} \qquad (3)$$

Now, define $m_i(t)$ to be the membership measurement at one of two regions determined by the gray level i for each gray level *t*. The membership measurement function can be defined as:

$$m_i(t) = \frac{1}{1 + \dfrac{d(t, \mu_{low}(i), \mu_{high}(i))}{I_{\max} - 1}} \qquad (4)$$

That function *d* $(t, \mu_{high}(i), \mu_{low}(i))$ is defined as follows:

$$d = \begin{cases} |t - \mu_{low}(i)| & t \le i \\ |t - \mu_{high}(i)| & t > i \end{cases} \qquad (5)$$

By function *d* (.) the distance between any level of intensity t and the average corresponding area is calculated [3].

$$C_i = \sum_{t=0}^{I_{\max}-1} \left[m_i(t) * (1 - m_i(t)) \right]^2 \quad (6)$$

Based on the above definition, the image I is binarized using a threshold I_0 in which C_i is minimized [11]. The result of this stage is shown in Fig. 3 (c) for a slice of CT data of a patient.

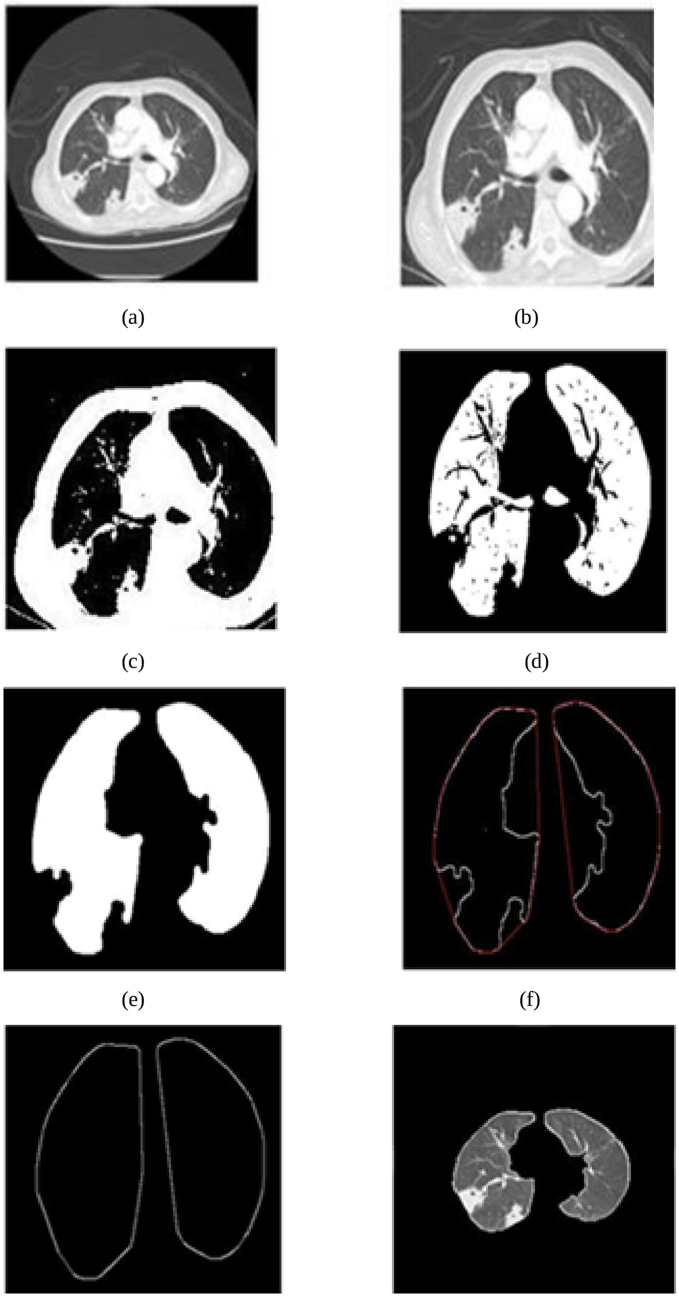
B. The Extraction of Lung Border

In this stage the exacted border of the lung is calculated using level set [12] and convex hull tools, which was proposed by Chunming Li et al [14]. For determination of Lung border, level set model that is able to simultaneously segment the image and estimate the bias field, and estimate the bias field has been used. The advantage of this model is that, the location of the initial mask does not affect the determination of lung border, and in this paper two automatic points are used. The initial mask is converged by determining the parameters of internal iteration 10 and external iteration 30, and parameter scale 4 towards the lung border. In this method, with regards to the fact that in the CT images each slice does not differ much from the previous slice, the contour obtained in each slice will act as the initial contour in the next slice. The result of this stage is shown in Fig. 3 (d) for a slice CT data of a patient [13].

The image presented in the previous section— for segmentation of thick slices with nodules attached to the wall— was not effective enough and therefore in the next stage convex hull algorithm method is used to segment the nodules. At first the image obtained from the previous stage is filled by morphology operators and then lung border is specified. In order to use this algorithm, the input points should be calculated. For this reason, at first the center of each lobe of the lung was specified and then the radius was stretched until it cut the lung border. Points obtained are considered as input of convex hull algorithm. The result of this stage is shown in Fig. 3 (e), (f), (g) for a slice CT data of a patient.

C. Post-Processing

The image obtained from the previous stage, does not fully segmented the internal district between the two lobes of the lung due to its concavity, therefore by using lung lobe feature the final processing is done. At this stage, from the border points obtained in the previous stage, in the lobe of the right lung, points were determined with the minimum row and columns, and the border obtained in level set model is replaced by the line formed by the convex hull algorithm. The same is done for the left lung lobe. The final result of lung segmentation is shown in Fig. 3 (g) for a slice CT data of a patient.



(a) (b) (c) (d) (e) (f) (g) (h)

Fig. 3. All intermediate results of our lung segmentation algorithm. (a) Original image. (b) result of cropped the original Image. (c) result of using the adaptive fuzzy thresholding. (d) result of the using level set method. (e) result of filling by morphology operators . (f) result of using from convex hull algorithm. (g) result of extraction of border. and (h) final segmented lung by post-processing.

III. EXPERIMENTAL RESULTS

A. Data Set

In this section, the proposed algorithm of CT images containing three groups has been tested. The first data sets consisted of eight patients with 19 nodules. These data were provided by TABA (medical imaging center of Shiraz medical school) imaging center [5]. The second group, presented by Ginneken et al. [15] was provided from ANODE09. This group consisted of five patients with 39 nodules. The third group is the ELCAP (Early Lung Cancer Action Program) data from LIDC data sets. [16] This group included 50 patients with 397 nodules. Further details about data sets are presented inTable1.

B. *Experiment Results Based on Level Set*

In the presented paper, initially the adaptive fuzzy threshold of lung binary is done, and then the exact lung border is determined using level set tools. In the next stage, convex hull algorithm is used to segment of nodules attached to the lung wall, and in the end the features of lobe shape is used, and the border obtained in level set model is replaced by the line formed by the convex hull algorithm between these two points. Fig. 3 is the result of segmentation of lungs that indicates the ability of the proposed method for segmenting lungs. Because in this way the accurate border of the lung are obtained, as well as both large and small nodules attached to the lung wall. For accurate measurement of the lungs, four parameters, specificity, sensitivity, accuracy, false positive rate which shows the accuracy or quality of segmentation are used. These are presented in Table 2. Fig. 4 is the visual comparative result of the method presented in this paper along with a presented method by Ye [3]. This has been extracted from [9].

IV. CONCLUSIONS

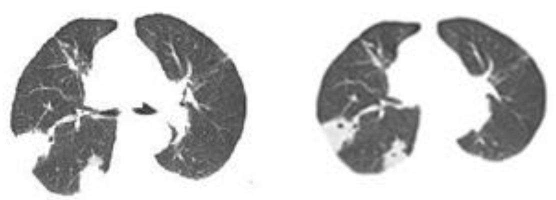
In this paper, we first expressed the introductions required to identify the lung images. Then the previous methods of lung segmentation were reviewed. The disadvantage of previous methods was mainly in the segmentation of lung nodules attached to the wall. This was solved with an automatic method. Level set model is used lung segmentation and with convex hull algorithm nodules are extracted from the walls.

TABLE I. CHARACTERISTICS OF OUR DATA SETS CATEGORIZED IN THREE GROUPS.

data	***Number of scans per group***	***Thickness***	***Number of nodules per type***	***LW attached***
Clinical	8	5	19	11
ANODE09	5	1	39	11
LIDC	50	1.25	397	155

TABLE II. ACCURACY OF PROPOSED METHOD

Sensitivity	***Specificity***	***Accuracy***	***False positive rate***
0.907	0.98	0.984	0.001



(a) (b)

Fig. 4. Comparison of our lung segmentation method with proposed method in [3]. (a) Segmented lung by Ye's algorithm [2]. Failed segmentation for large non-isolated nodule. (b) Segmented lung by our method.

REFERENCES

[1] Y. Zheng, K. Steiner, T. Bauer, J. Yu, D. Shen, C. Kambhamettu, Lung nodule growth analysis from 3D CT data with a coupled segmentation and registra- tion framework, in: Proceedings of the IEEE Computer Vision Conference, , pp. 1–8, 2007.

[2] C. Lei, L. Xiaojian, Z. Jie, C. Wufan, Automated lung segmentation algorithm for CAD system of thoracic CT, J. Elsevier Med. Coll. PLA 23 (2008) 215–222.

[3] X. Ye, X. Lin, J. Dehmeshki, G. Slabaugh, and G. Beddoe, Shape-based computer-aided detection of lung nodules in thoracic CT images, IEEE Trans. Biomedical Engineering, vol. 56, pp. 1810-1820, Jul. 2009.

[4] S. Taghavi Namin, H. Abrishami Moghadam, R. Jafari, M. Esmaeil-Zadeh, and M. Gity, Automated detection and classification of pulmonary nodules in 3D thoracic CT images, in Conf. 2010 IEEE SMC, pp. 3774-3779.

[5] S. Shimoyama, N. Homma, M. Sakai, T. Ishibashi, and M. Yoshizawa, Auto-detection of non-isolated pulmonary nodules connected to the chest walls in X-ray CT images, in Conf. IEEE ICCAS-SICE, pp. 3672-3675,2009.

[6] J. Lai, and M. Ye, Active contour based lung field segmentation, in Conf. 2009 IEEE IHMSC, pp. 288-291.

[7] G. RGranavi, A. Baraani-Dastjerdi, H. Abrishami Moghaddarn, M. Giti, and A. Adjdari Rad, A new segmentation method for lung HRCT images, IEEE Proc. 2005 8th DICTA, Cairns, Australia.

[8] S. Yamamoto, M. Nakayama, M. Senda, M. Matsumoto, Y. Tateno, T. Iinuma, and T. Matsumoto, A modified MIP processing method for reducing the lung cancer X-ray CT display images", medical imaging technology, vol. 12, no. 6, pp. 737-747, 1994.

[9] M. Keshani, Z. Azimifar and R. Boostani, F. Tajeripour, Lung nodule segmentation and recognition using SVM classifier and active contour modeling: A complete intelligent system, J. Elsevier of Computers in Biology and Medicine, 43 (2013) pp.287–300, 2012.

[10] H. R. Tizhoosh, Fuzzy Image Processing. New York: Springer-Verlag, 1997.

[11] R. C. Gonzalez and R. E. Woods, Digital Image Processing, 2nd ed. Reading, MA: Addison-Wesley, 2002.

[12] Y. Ebrahimdoost, J. Dehmeshki, T. S. Ellis, M. Firoozbakht, A. Youannic, SD. Qanadli, Medical Image Segmentation Using Active Contours and a Level Set Model: Application to Pulmonary Embolism (PE) Segmentation, IEEE Fourth International Conference on Digital Society, PP. 269-273, 2010.

[13] P. Guo, G. Hongyu, D. Jianping, A Novel Lung Segmentation and Boundary, Correction Method, In conf. IEEE Biomedical Engineering, PP. 1-4,2009.

[14] C. Li, R .Huang, Z. Diang, J. Gatenby, N. Metaxas, A Level Set Method for Image Segmentationin the Presence of Intensity Inhomogeneities, IEEE Trans. Image Processing, vol.20, PP. 2007-2016.2011.

[15] B. V. Ginneken, S. G. Armato, B. Hoop, S. V. Amelsvoort-van de Vorst, T. Duindam, M. Niemeijer, K. Murphy, A. Schilham, A. Retico, M. E. Fantacci, N. Camarlinghi, F. Bagagli, L. Gori, T. Hara, H. Fujita, G. Gargano, R. Bellotti, S. Tangaro, L. Bolaos, F. D. Carlo, P. Cerello, S. C. Cheran, E. L. Torres, M. Prokop, Comparing and combining algorithms for computer-aided detection of pulmonary nodules in computed tomography scans: The ANODE09 study, J. Elsevier of Medical Image Analysis, vol. 14, pp. 707-722, 2010.

[16] http://www.via.cornell.edu/databases/lungdb.html.