Segmentation of Lung Vessels Together With Nodules in CT Images Using Morphological Operations and Level Set Method

Trang K. Le
IMT (Institut de Mathématiques de Toulouse Université Paul Sabatier)
Toulouse Mathematics nstitute, Paul Sabatier University
E-mail: lekimtrang9758@yahoo.com

***Abstract*—With a fast development of computer tomography (CT) technology, CT images has become one of the most efficient examination methods of lung diseases in clinical. The appearance of vessels and nodules together with their changes over the time in CT images may provide an exact diagnosis. Segmenting blood vessels, extracting nodules together with distinguishing between vessel junctions and nodules have become important clinical challenges. Some factors usually used to distinguish between blood vessels and nodules include the structure, shape, size, color and intensity differences, i.e. bright light or shady. The precision of segmenting lung vessels and nodules plays an important role in analyzing the volumetric growth rate and the nodule status. There are many applications of image processing techniques proposed and used nowadays to give radiologists necessary information in their work such as vessel enhancement, nodule enhancement, vessel and nodule segmentation, etc. With the recognition that intensity is one of the most important factors in classifying strong and weak vessels, solid and nonsolid nodules, this paper presents a way of segmenting vessels together with nodules in CT lung images into three levels of the intensity using morphological operations and level set method. Level-1 indicates the highest intensity or bright light regions, level-3 includes the lowest intensity or shady grayish regions and level-2 is middle level.**

***Index Terms*—CT lung image, vessel and nodule segmentation, morphological operation, level set method.**

I. Introduction

Computer tomography (CT) is a well-known technique nowadays in offering high resolution images for radiologists to diagnose and detect lung diseases. Two among the important tasks in interpreting lung CT images are segmenting vessels and finding nodules. Some factors used for recognizing vessels and nodules are the structure, shape, size, color, intensity, the changes as well as volumetric growth over the time or over some consecutive frames of CT images. For instance, blood vessels conform to a tubular shape while nodules conform to a spherical shape [1]. A blood vessel will have a connection to the next image frame and gradually fade out in a vessel which appears as a branch [2]. When a contrast agent is used in CT images, higher uptake of contrast agent appears in white color, strong vessels appear brighter or whiter than the nonsolid nodules and the lung parenchyma. Nonsolid or shady nodules tend to be stable and grow more slowly than the lighten ones [2]. Changing in the size of nodules over the time is one of the main elements in analyzing nodule status, some nodules might increase or vanish. The precision of segmenting lung vessels and nodules plays an important role in analyzing the volumetric growth rate and the nodule status. There are many applications of image processing techniques proposed and used nowadays to give radiologists necessary information in their work such as vessel, junction and nodule enhancement using probabilistic model-based filter [1], vessel segmentation using Voxel classifier then nodule segmentation by applying vessel removal filter [3], automatic detection of small lung nodule [4], segmentation of lung lobes and nodules using morphological operations, thresholding and region growing method to refine oblique fissure [5], lung cancer detection using Gabor filter and Watershed segmentation method [6], segmentation algorithm for CT images using morphological operation and artificial neural network [7], etc. With the recognition that intensity is one of the most important factors in classifying strong and weak intensity vessels, solid and nonsolid nodules, this paper presents an automated way of extracting lung vessels together with nodules from CT images and classifying them into three levels of intensity: highest intensity, middle level and lowest intensity. The main techniques used in this study are region growing for lung segmentation, morphological operations and level set method for vessels and nodules extraction.

II. Data and Method

A. Data

Experiments were conducted using the data obtained from http://www.website-go.com/acc/ and VIA/I-ELCAP Public Lung Database. The ELCAP dataset contains gray-scale CT scan images of the whole lung for diagnosis, includes 50 CT scans of a single breath hold, and the ground-truth locations of nodules.

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B. Methods

Fig. 1 shows a general description of lung vessel together with nodule segmentation system that contains three main stages. The first stage includes three basic steps: segmenting lung using region growing, then enhancing the output images using morphological operations, finally extracting vessels together with nodules by applying level set method. If there is a difficulty in segmenting lung using region growing (in case there is white regions lie at the boundary), the contrast of image will be enhanced first using histogram equalization before applying region growing. The second stage includes two steps: converting original grey-scale images to binary images and enhancing the output images using morphological operations to extract vessel and nodule belong to level-1 intensity group, i.e. the highest intensity one. In the final stage the output image of stage 1 and stage 2 will be combined to extract vessels together with nodules of three levels.

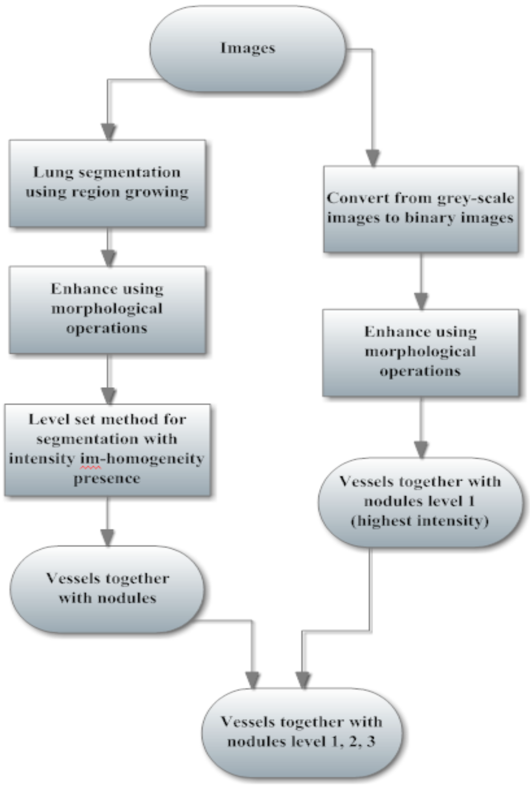


Figure 1. General description of the system.

C. Morphological Operations

Morphological operations are well known for extracting useful information of region shape and structure in images, such as skeletons, boundaries and convex hulls [8]. Morphological operations rely on set theory, thus a set of operators as union, intersection, inclusion and complement can be applied, they are used in the preliminary and final processing on images such as thickening, thinning, filtering or enhancing [9]. The input data for mathematical morphology are the image and the structuring element. Structuring element used in practice is typically much smaller than the processing image and can be seen as a description of the area in some specific form. The structuring element is often a 3*3, 4*4 or 5*5 matrix. The reason is in the operation, morphological processing will search for specific image detail, highlight or remove desired items on the whole image [9].

The basic operations of morphology are dilation, erosion, opening and closing [10]. Besides these operations, top-hat and bottom-hat transformations are also well-known for morphological filtering in image processing and enhancing. Top-hat transformation is an operation that extracts small elements and details from the given images. The top-hat transform is computed by subtracting the image's opening from the original image, while the bottom-hat transform is calculated as the difference between the image's closing and the original image.

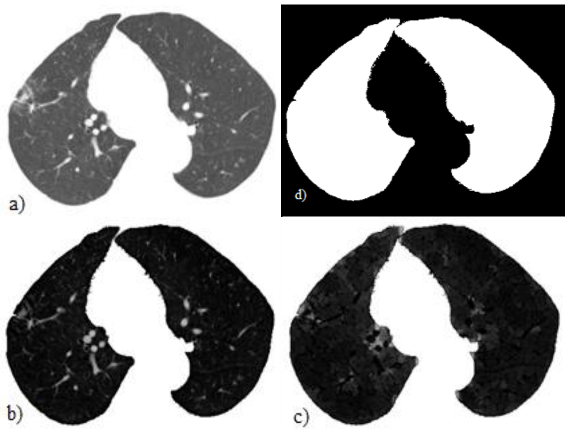


Figure 2. a) Original image, b) Top-hat image, c) Bottom-hat image, d) Lung mask

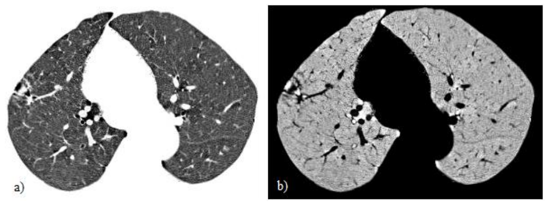


Figure 3. a) Enhancement image, b) Complement of enhancement image.

This paper proposed a way to combine morphology with level set method to extract strong and weak intensity vessels together with solid and nonsolid nodules. First of all, contrast enhancement is applied to each image by combining the use of top-hat and bottom-hat transformation. To maximize the gaps that separate objects from each other and therefore maximize the contrast between the them, the original image is added to the top-hat image, after that subtracts the bottom-hat image from the result. To highlight the intensity valleys, complement operation is applied on the enhanced image. Fig. 2 shows top-hat and bottom-hat lung CT images, and Fig. 3 is an example of enhancement image and the complement of this enhancement.

Morphology operation on image = Complement(Input image + top hat image - bottom hat image)

D. Level Set method

Region based methods for segmentation usually rely on the intensity homogeneity on different regions of interest, they often fail to give exact results when encountering intensity imhomogeneity. To deal with this problem, level set method was proposed by C. Li and his colleagues in 2011, their method is also region based one but faster, more robust and accurate than piecewise smooth model [12]. Lung CT images belong to the group of images which contain regions of intensity imhomogeneity. This attribute suggests the use of level set method will populate promising results in vessel and nodule segmentation application.

III. Experiment Results

A. Experiment 1

There were two experiments in this study. The first experiment used 50 cases of 50 CT scans derive from the website of VIA-ELCAP lung image database [11], these cases are named from W0001 to W0050. Database contains 512x512 images having 96 dpi resolution with 8 bit depth. In each case, some images were picked to join in the experiment so that the total number of images used was 100 in this experiment. They are consecutive frames getting from case W0001 to case W0050 in which the middle frame would contain nodule. This experiment only evaluate qualitative results of three modes. Mode 1 (level-1, 2): segmentation outcome when calling level set evolution and bias field estimation 3 times, this mode contains only vessels and nodules of level-1 and 2.

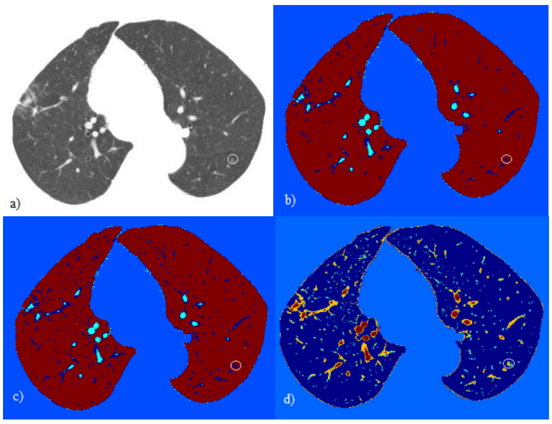


Figure 4. Vessel segmentation results of frame 73, case W0046. a) Original image. b) Cyan: level-1, Blue: level-2. c) Cyan: level-1, Blue: level-2,3. d) Red: level-1, Orange: level-2, Cyan: level-3. White circle: nodule position.

Mode 2 (level-1, 2, 3): the outcome when calling level set evolution and bias field 25 times. This mode contains vessels, nodules of three levels and there is no distinction between level 2 and level 3. Mode 3 (level-1, 2, 3): the result when calling level set evolution and bias field 25 times. This mode also contains vessels and nodules of three levels but there is a distinguishing between level-2 and level-3.

Structuring element in morphological operations is a disk with radius equals to 7. Sigma parameter which is the scale parameter that specifies the size of the neighborhood in level set method [12] was kept at 4.

Fig. 4 shows vessel segmentation results of frame 73 in case W0046, with a) is original image, b) is the outcome of mode 1, the result contains level-1 and level-2 vessels or nodules. c) is the outcome in mode 2 and d) is the combination of c) and b) which generates three levels of segmentation of mode 3. In images b) and c), cyan color indicates level-1 (highest intensity), while blue color shows level-2 or level-3. In image d) red color is the highest intensity regions (level-1) which can be strong vessels or solid nodules, orange color means middle level (level-2) and cyan color are the lowest intensity regions (level-3) which can be weak vessel junctions or tiny non-solid nodules. The white circle in each image is the nodule derived from the ground-truth database.

More qualitative results of the experiments are provided in the appendix section.

By inspecting multiple consecutive frames, nodule can be detected as shown in Fig. 5 There is a bright sphere appears in frame 145 while in frame 143 and 144 it is opaque. This bright sphere tends to reduce its intensity in frame 146 and 147 and disappears in frame 148. This suggests that the bright sphere in frame 145 would be a nodule. Fig. 6 is another example for detecting nodule from some consecutive frames.

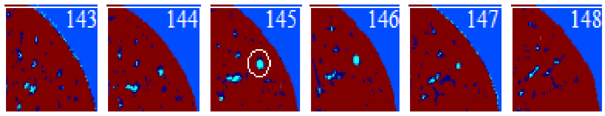


Figure 5. Montage view of mode 1 for frame 143 to frame 147, case W0019. White circle: nodule position.

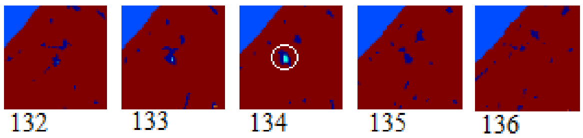
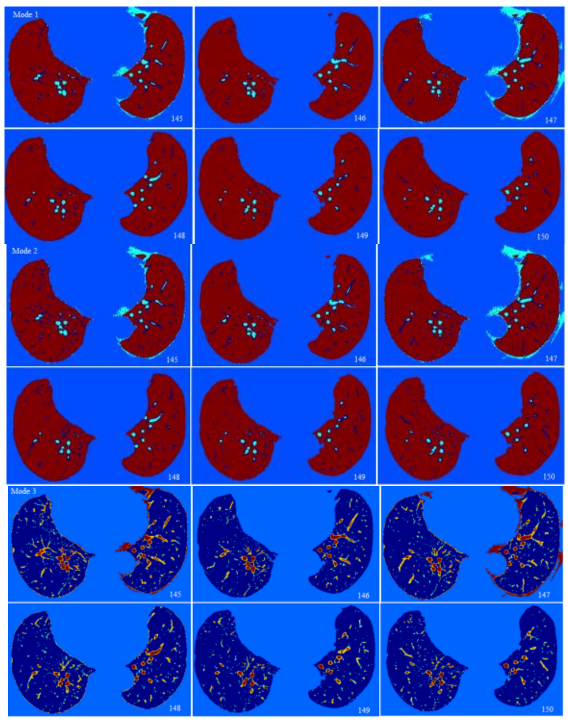


Figure 6. Montage view of mode 1 for frame 132 to frame 136, case W0048. White circle: nodule position.

Figure 7 shows the whole lung segmentation from frame 145 to frame 150 of case W0046.



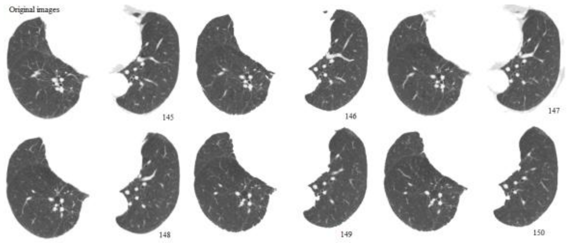


Figure 7. Montage view of mode 1,2,3 frame 145 to 150, case W0046.

B. *Experiment 2*

Experiment 2 used images obtain from the website http://www.website-go.com/acc/. These images have 96dpi resolution with 24 bit depth. This experiment again evaluate qualitative results of three modes. Fig. 8 shows the outcome of segmenting lung vessels which contains a lesion. Fig. 9 is another result of this method on a CT lung image contains nodules or metastases with a nonsolid, low alighted or shady appearance [2].

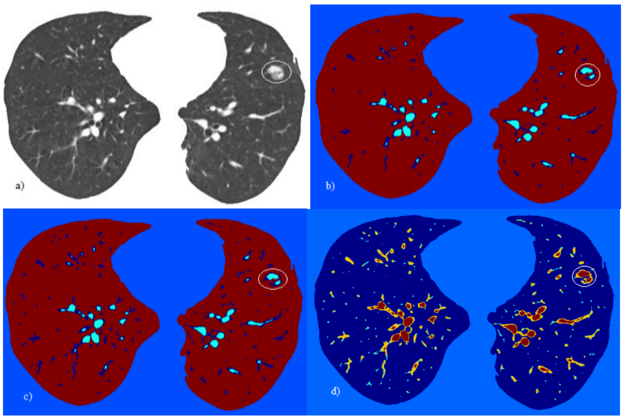


Figure 8. Vessel segmentation results. a) Original image. b) Cyan: level-1, Blue: level-2. c) Cyan: level-1, Blue: level-2,3. d) Red: level-1, Orange: level-2, Cyan: level-3. White circle: nodule position.

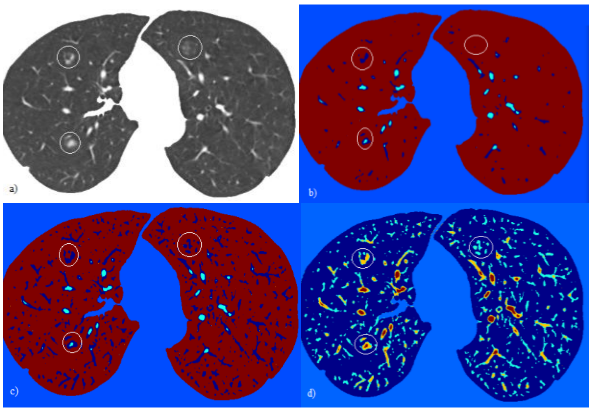


Figure 9. Vessel segmentation results of an image contains nodules with a nonsolid or shady appearance.

IV. DISCUSSION AND CONCLUSION

The qualitative evaluation in both experiments showed that mode 3 gives a more detail of vessel structure than mode 1 and mode 2. In caring of the whole vessel system, mode 2 and 3 will be better than mode 1 in this study, moreover, mode 3 will give more detail in intensity differences. Weak vessels, weak junctions of vessels, tiny and non-solid nodules is usually detected in this mode. Besides that, strong vessels and solid nodules usually fall into level-1 and level-2 because of their high intensity. Therefore, in searching strong vessels and solid nodules over some consecutive images, mode 1 tends to be better than mode 2 and mode 3 in this work as mode 1 reduce unnecessary information of level-3. Mode 1 will not show information about tiny vessels or tiny junctions of vessels and non-solid nodules, thus it makes the images more clear to give an easier way for searching solid nodules. Level set method can recognize the boundary of inner bronchus. The size of nodules in images of experiment 2 is bigger than experiment 1, and the images in experiment 1 are clearer therefore the detection of nodule is easier for examination than in experiment 1.

APPENDIX A SOME EXPERIMENT OUTCOMES IN EXPERIMENT 1

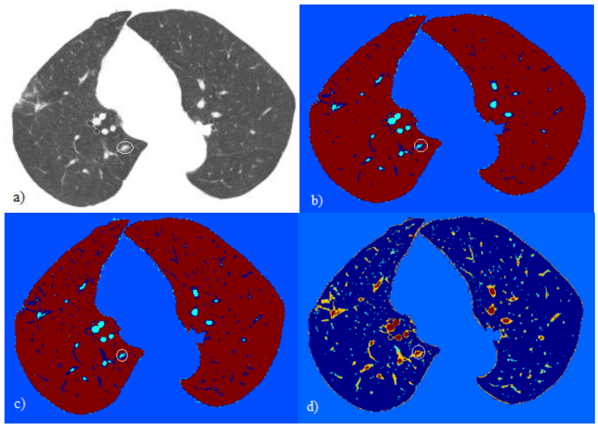


Figure 10. Frame 72, case W0046

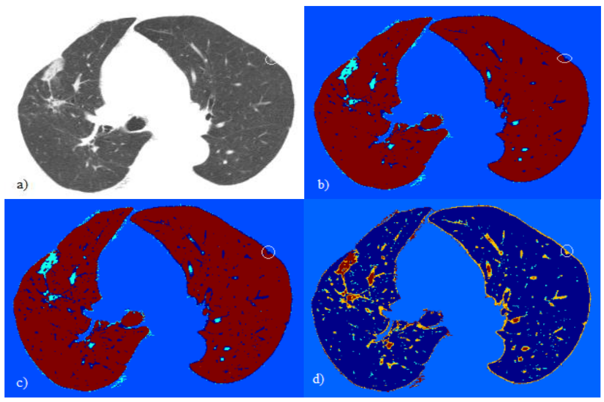


Figure 11. Frame 86, case W0046

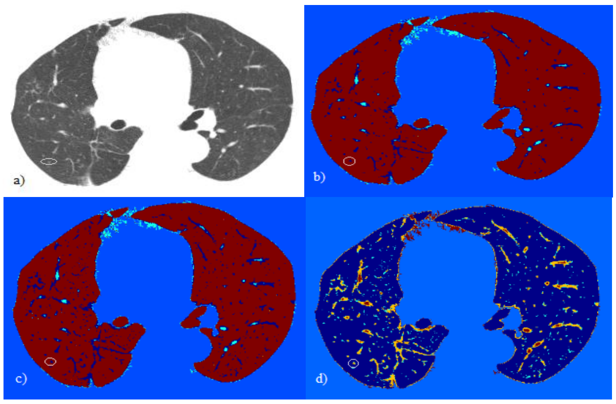


Figure 12. Frame 101, case W0046

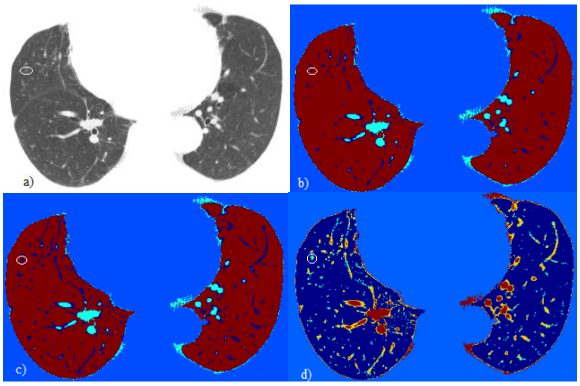


Figure 13. Frame 141, case W0046

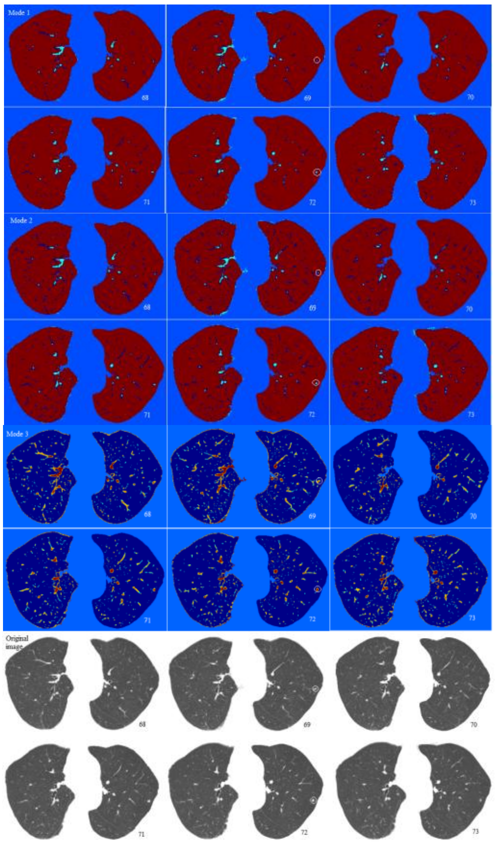


Figure 14. Montage view of mode 1,2,3 frame 68 to 73, case W0035

APPENDIX B SOME EXPERIMENT OUTCOMES IN EXPERIMENT 2

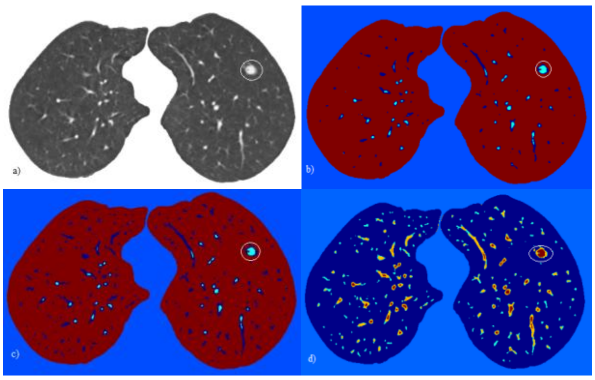


Figure 15. CT lung image contains a typical round shaped nodule, bright light

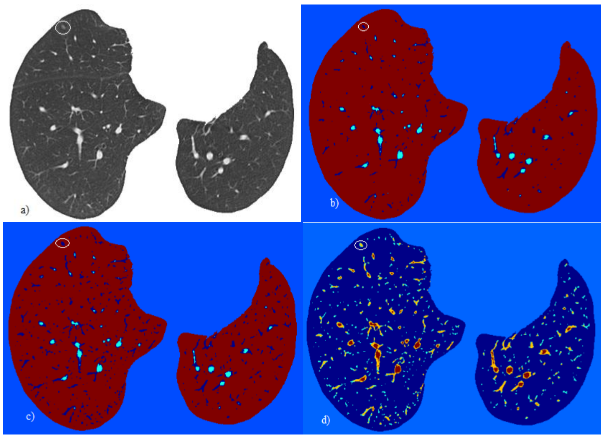


Figure 16. A small hiding nodule with low brightness

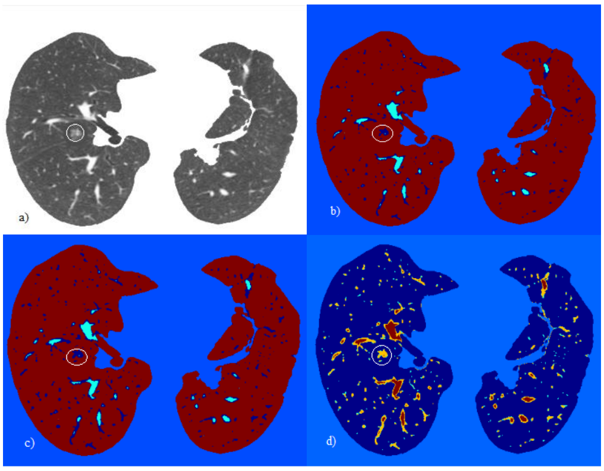


Figure 17. CT lung image contains a shady, non-solid nodule

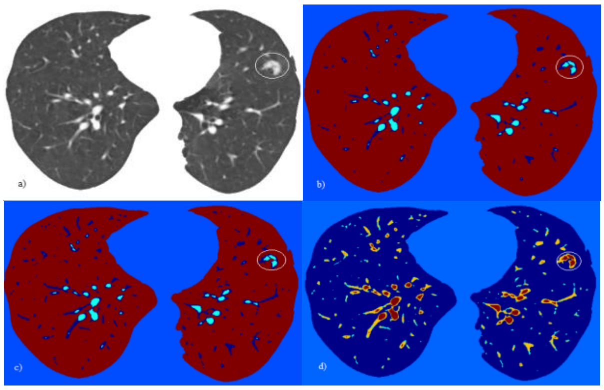


Figure 18. CT lung image contains a solid nodule

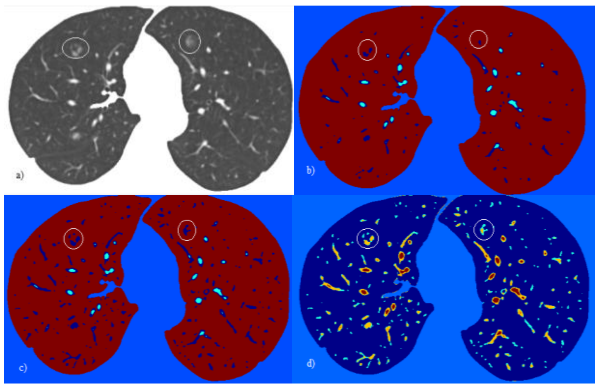


Figure 19. An example of CT lung image with vanishing lesion

REFERENCES

[1] C. Wu and G. Agam, "Probabilistic nodule filtering in thoracic CT scans," *Medical Imaging*, J. P. Pluim and J. M. Reinhardt, eds., Proc. SPIE, 2007.

[2] How to Interpret ct Scan of Your Lung. (15 October 2012) [Online]. Available: http://www.website-go.com/acc/

[3] W. A. Browder, "The segmentation of nonsolid pulmonary nodules in CT images," Master thesis, Cornell Uni, 2007.

[4] B. Zhao, G. Gamsu, M. S. Ginsberg, L. Jiang, and L. H. Schwartz, "Automatic detection of small lung nodules on CT utilizing a local density maximum algorithm," *Journal of Applied Clinical Medical Physics*, vol. 4, no. 3, 2003.

[5] S. Anitha and S. Sridhar, "Segmentation of lung lobes and nodules in CT images," *International Journal of Signal Processing and Image Processing*, vol. 1, no. 1, 2010.

[6] M. S. Al-tarawneh, "Lung cancer detection using image processing techniques," *Leonardo Electronic Journal of Practices and Technologies*, no. 20, pp. 147-158, 2012.

[7] C. Karthikeyan, B. Ramadoss, and S. Baskar, "Segmentation algorithm for CT images using morphological operation and artificial neural network", *International Journal of Signal Processing*, vol. 5, no. 2, 2012.

[8] S. Dinesh and P. Radhakrishnan, "Linear and nonlinear approach for DEM smoothening," *Discrete Dynamics in Nature and Society*, vol. 2006, 2006.

[9] Introduction to Morphology Operations on Images. (15 October 2012). [Online]. Available: http://computer-vision-talks.com/2011/02/introduction-to-morphology-operations-on-images/

[10] Morphology Fundamentals: Dilation and Erosion. [Online]. Available: http://www.mathworks.com/help/images/morphology-fundamentals-dilation-and-erosion.html#f18-24720?s_tid=doc_12b

[11] ELCAP Public Lung Image Database. [Online]. Available: http://www.via.cornell.edu/databases/lungdb.html

[12] C. Li, R. Huang, Z. Ding, C. Gatenby, D. N. Metaxas, and J. C. Gore, "A level set method for image segmentation in the presence of intensity inhomogeneities with application to MRI," *IEEE Trans. Image Processing*, vol. 20, no. 7, pp. 2007-2016, 2011.