

Adaptive Enhancement Technique for Cancerous Lung Nodule in Computed Tomography Images

Ayman A. AbuBaker

Electrical and Computer Eng. Dept., Applied Science Private University,
Shafa Badran, Amman, Jordan
a_abubaker@asu.edu.jo

Abstract— Diagnosis the Computed Tomography Images (CT-Images) may take a lot of time by the radiologist. This will increase the radiologist fatigue and may miss some of the cancerous lung nodule lesions. Therefore, an adaptive local enhancement Computer Aided Diagnosis (CAD) system is proposed. The proposed technique is design to enhance the suspicious cancerous regions in the CT-Images. The visual characteristics of the cancerous lung nodules in the CT-Images was the main criteria in designing this technique. The new approach is divided into two phases, pre-processing phase and image enhancement phase. The image noise reduction, thresholding process, and extraction the lung regions are considered as a pre-processing phase. Whereas, the new adaptive local enhancement method for the CT-Images were implemented as a second phase. The proposed algorithm is tested and evaluated on 42 normal and cancerous lung nodule CT-Images. As a result, this new approach can efficiently enhance the cancerous lung nodules by 25% comparing with the original images.

Keyword-Cancer Detection, Computed tomography, Digital images, DICOM, Image enhancement.

I. INTRODUCTION

Lung cancer is one of the serious public health problems in many countries such as United States, Europe, and Middle East [5]. Many of men and women are dead yearly from the late diagnosis of lung cancer. Detection and treated this cancer in an early stage is require to effectively overcome this burden. Chest X-ray is an initial and cheapest method to detect the lung cancer. Whereas, Computed Tomography (CT) images has recently been the best imaging modality for the detection of small pulmonary nodules [7][22]. However, the amount of data storage that need to be interpreted in CT examinations are very large, especially when multi-detector helical CT and thin collimation are used, thus generating up to about 300 two-dimensional images per scan, corresponding to about 150 MB [8][10].

Support radiologists by identification in an early-stage pathological objects can enhance their work [11]. Therefore, researchers have recently begun to explore computer-aided detection (CAD) methods in this area to help the radiologist and reduce their effort. CAD systems may help radiologists in interpreting for cancerous lung nodules images detection and enhancement. Since 70% to 90% of the biopsies of suspected cancers turned out to be benign, it is very important to develop CAD systems that can distinguish benign and malignant lesions [11]. The combination of CAD scheme and experts' knowledge would greatly improve the detection accuracy. Using the CAD system can increase of the sensitivity of detecting the suspicious regions by 80% for the radiologist comparing with traditional diagnosis method [19].

Cancerous lung nodule enhancement is one of the difficult problem because they are closely connected to the surrounding parenchymal tissue. Therefore, a non-uniform tissue background with similar visual characteristics usually surrounds them. Therefore, this paper presents an ongoing effort to enhance the cancerous lung nodules in order to be clearly noticed by the radiologist using multi statistical method. Image noise reduction, thresholding and lung regions extraction are implemented as a pre-processing stage. Then a novel enhancement technique is implemented to enhance the suspicious cancer nodules in the CT images.

In this paper, the lung CT database used in this work are described section II. A brief survey of previous work is presented in Section III. The proposed enhancement technique is introduced in Section IV. The algorithm evaluations are presented in Section V, while concluding remarks are given in Section VI.

II. LUNG CT DATABASE

A lung CT dataset was acquired from The Cancer Imaging Archive (TCIA), which is organized into purpose-built collections of subjects [2]. The subjects typically have a cancer type and/or anatomical site (lung, brain, etc.) in common. This database include a huge dataset of different type of cancer cases such a brain, breast, bladder, lung cancers. To support reproducibility in scientific research, TCIA supports Digital Object Identifiers (DOIs) which allow users to share subsets of TCIA data referenced in a research manuscript. In this

database, all the images are stored in DICOM file format and are organized as “Collections”, typically patients related by a common disease (e.g. lung cancer), image modality (MRI, CT, etc) or research focus.

III. LITERATURE SURVEY

A CAD system is one of the significant tools that can help in the diagnosis of CT images. A major limitation in developing computerized methods for CT image interpretation arises from the difficulty of demonstrating that algorithm performance meets the very high caliber needed to make accurate decisions. Therefore, several authors had investigated different techniques to enhance and detect the cancerous lung nodules regions. One of these techniques, described by ChengZhenghao Shi et al [4], Laplacian of Gaussian filter is used to enhance the nodules in a chest radiograph. Moreover, they used the transmission of high intensity first and the LOG filter is applied to calculate the differences in contrast within inside and outside region of interest. Other technique, like Vivekanandan D et al [17] used snake algorithm to segment the CT images. A snake algorithm is used as a tool for the energy function in term of internal energy and force that acts on image. On the other hand, other authors implement the enhancement algorithm for chest X-ray such as Messay et al. [15]. Where, they employed a local contrast enhancement filter that followed the nodule enhancement method used for the chest radiographs. Li et al. [9] apply three different enhancement techniques on CT images. The dots, lines, and planes enhancement techniques are proposed that can simultaneously enhance objects of a specific shape and suppress other objects. So, initially they blurred the CT image with a Gaussian kernel that matched the size of the nodule to be detected then, they calculating the eigenvalues of the Hessian matrix that were used for selective enhancement. Finally, multiple scales of the Gaussian kernel are used to find a match with the nodule size. A statistical enhancement filter is also used by Yamamoto et al. [1]. They proposed a statistical enhancement filter, the Quoit Filter that has large ring and disk filters. The filter can successfully enhances the nodule by calculating the difference in the output of the ring and disk filter. In addition, they proposed a three-dimensional (3D) extension. As a second phase in CAD system is the segmentation algorithm. One of most significant techniques in segmentation algorithm is applied by Maciej Dajnowiec et al. [18]. They successfully proposed a novel method for automatic segmentation of the lung region. In this method optimum threshold value was calculated from the image of the data set. This threshold values are used to differentiate the organ and solid tissue from air region of the lung. Then, the images is sequentially checked from the beginning until the two objects whose size exceeds 1% of the total pixel were found. It was considered as base slide. Then the region growing technique is applied to obtain the remaining region in the image. Finally, the proposed lung portion mask is multiplied with the original CT images to extract the lung portion of each slide. As a result they can segment lung nodule but have lobes with nodules region. Detection the cancerous nodules in the CT image is another challenge that many author try to achieve high sensitivity in detection the tumors. Lee et al. [3] proposed a new template matching technique to detect lung nodules in chest CT scans. A genetic algorithm is used as a tool in this proposed detection algorithm to determine the target position and also to select a template image from the reference patterns. Four generation of templates are established according to the gray-level values of 3D Gaussian distributions. The algorithm present good sensitivity in detection the cancerous nodules in the CT-images. The distance transformation technique is proposed by Opfer et al [13] in order to improve the CAD system. The proposed CAD system is design based on using the distance transformations for various thresholds and subsequent crest line extraction. The proposed method can slightly improve the CAD system with large number of FP regions. Moreover, Golosio et al. [14] proposed other nodule detection method using multi-adaptive threshold surface triangulation approach. CT technology was also adopted by K.Devaki et al. [20] to acquire high resolution of the lungs in a single breath hold. Analysis of these large volumes of image data was manually performed, which was time-consuming task. Therefore, they used automated analysis of CT scan images by addressing segmentation result of various lungs anatomical structures.

IV. METHODOLOGY

CAD systems can improve the performance of a radiologist by enhancing the CT-images, segmenting the lung region with minimum artifacts and highlighting the suspicious regions in the CT images. Therefore, in order to have a robust CAD enhancement system, two main stages are followed as shown in Fig. 1. In the first stage, image noise reduction and thresholding, morphological and extraction the lung region are categorized as pre-processing stages then a novel enhancement algorithm is implemented as a second stage.

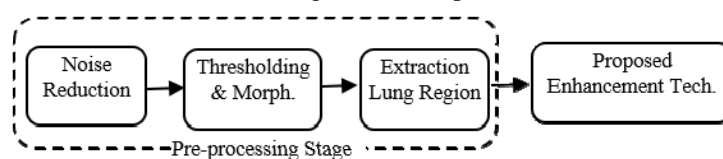


Fig. 1. CAD Enhancement Technique

A. Preprocessing the CT-Images

The preprocessing stage is an essential stage in any CAD system. In this stage, the CT images are processed to reduce the noise and remove any artifacts in the image. Then thresholding and morphological operation is applied on the image. Finally, the lung region is extracted to increase the efficiency of the enhancement algorithm.

- 1) *Noise Reduction*: Most of the CT dataset images have a common noise, which I considered it as salt and pepper noise that easily removed by a median filter. This stage consider as a very important stage in order to have a good extraction for the lung region. Fig. 2, shows the result of CT image after applying a median filter.

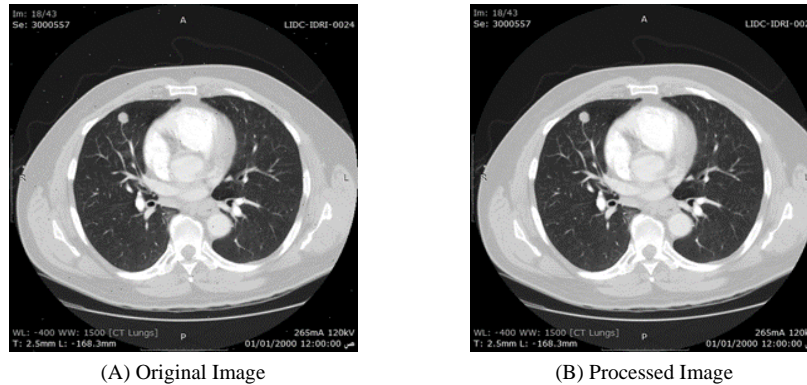


Fig. 2. Median Filter

- 2) *Thresholding and Morphological Operation*: CT images are a special type of digital image because of their high resolution. In these images, the extraction process is relatively hard since the background intensity is close to the lung region intensity as shown in image histogram that presented in Fig. 3. This will make the thresholding process more difficult than any other images. Many thresholding methods are implemented to precisely extract the lung regions. The most fast and significant algorithm was Otsu's method as shown in Fig. 4. In this algorithm, the lung borders are efficiently included in the thresholding process. Therefore, there will be no lose on information in the processed image.

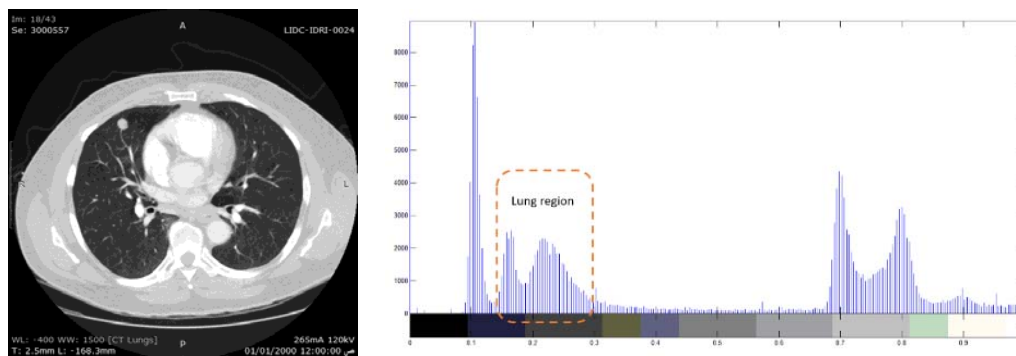


Fig. 3. The Image histogram of CT image

- 3) *Extraction Lung Region*: The last pre-processing stage is carried out by extraction the lung region in the CT images. The aim of this stage was to achieve an efficient technique that would extract all types of lung regions with different shapes. As shown in the previous section, the lung regions are shown as dark region close to the image background. Therefore, a novel extracting technique is proposed that can extract the lung region in the CT images effectively. This proposed technique is summarized as following:

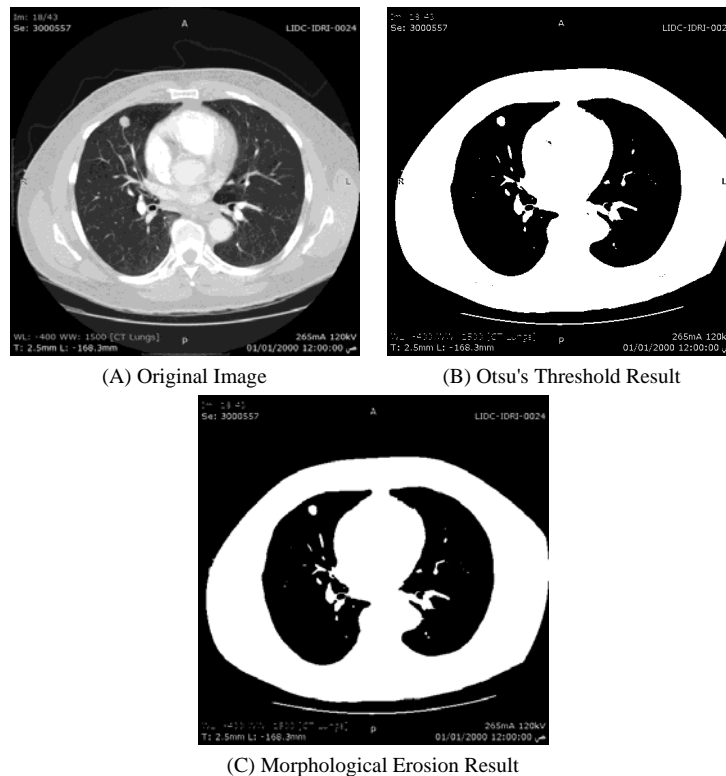


Fig. 4. Thresholding and Morphological Operation

• **Apply Connected Component Labelling Algorithm:** An object size filter is implement to detect the lung region only without background. Based on this, the size filter will detect the lung region based on the following steps:

1. One scan connected component that design by Abubaker et. al. [6] is implemented after modifying the algorithm to detect value (0) as an object instead of value (1). The main objective of the OSCCL is to give a unique label for each object in the CT image as shown in Fig. 5. Then the area for each object is computed in pixels.
2. The algorithm tuned so that include all the areas of different lung regions. Therefore, many CT images are processed and conclude that the best areas is 18000 to 25000 pixels. So, any object exceeded these areas will be set to 255 otherwise it will have a value zero as shown in Fig. 5.



Fig. 5. The OSCCL and negative image.

- **Negative Image:** The threshold image is inverted in order to highlight the lung regions as shown in the Fig. 5.
- **Segment the Lung Region:** As a final step, all the small regions inside the lung regions are eliminated using the object size filter that presented in the previous step. Then the original image is multiplied with the processed image. Fig. 6, show the extracted lung region effectively without background or any artefacts.

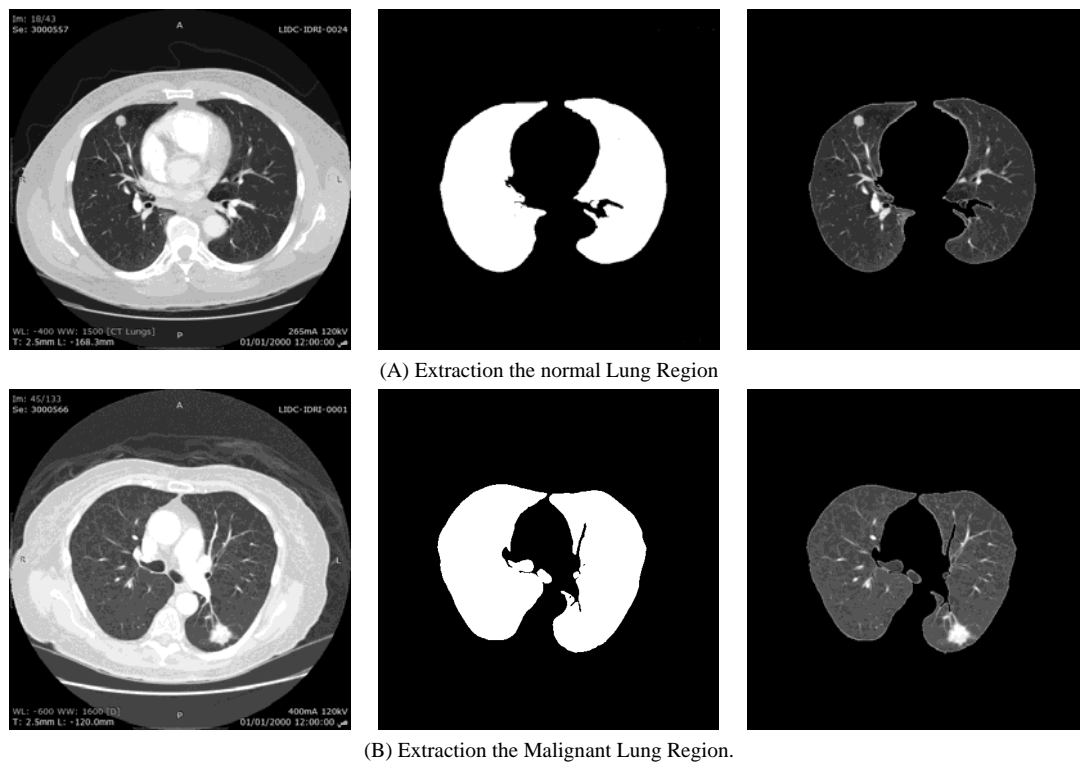


Fig. 6. Extraction the Lung Region.

B. Proposed Enhancement Technique

Computer-aided diagnoses (CAD) for enhancing the CT images are exciting as a great deal of attention from the radiologist community [16]-[17]. CAD is defined as a diagnosis made by a physician taking into account the computer output as a second opinion. The main goal of applying enhancement CAD system is to support radiologists' image interpretation and improve the diagnostic accuracy and consistency [16].

The proposed enhancement CAD system is a tool to help in increasing the intensity for the cancerous lung nodules in the CT images. The algorithm is design based on visual characteristics of cancerous lung nodules. The cancer tumor is visualized as a peak corresponding to the neighbor pixels in the CT Images. Therefore, a mask of size 21×21 is proposed to process the CT-image based on the following steps:

The variance value for the mask in each convolution iteration is computed. The variance value can measure the fluctuation for the pixels in the mask. In uniform regions, the variance will be very small comparing with an edge in the mask.

When the algorithm detect a high variance value in the mask, then there will be a peak in the mask. Therefore, a sharpening LoG filter is applied on the mask region only. Whereas, the mask that has a low variance value of inverse log algorithm is implemented on the pixel's mask.

The proposed algorithm is implemented on normal and cancerous CT-images as shown in Fig. 7.

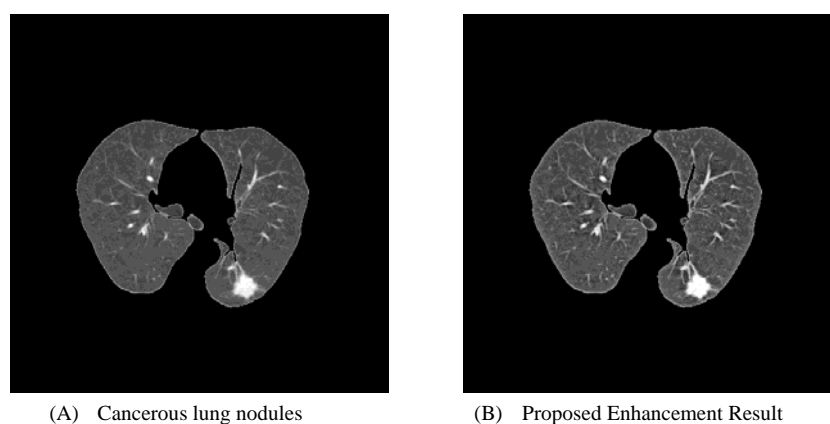


Fig. 7. Processing imaging using Enhancement Technique

V. ALGORITHM EVALUATION

Subjective and Objective evaluations are applied to the proposed enhancement algorithm. The subjective evaluation process is carried out by asking two CT-scan radiologists in two different hospitals about the quality of the image. Whereas, an objective evaluation algorithm is implemented to test the image enhancement quality.

A. Subjective Comparison

Twelve normal CT images and thirty cancerous CT images are selected from the TCIA database. These images are processed using the proposed enhancement algorithm. These images are randomly presented and listed for the radiologist and the evaluation for each case is recorded. The evaluation result is summarized in Table 1.

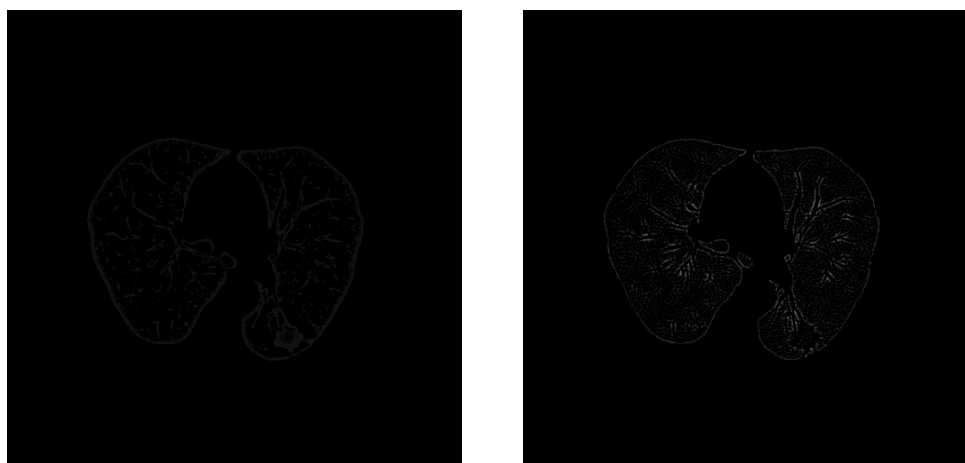
TABLE I. Image Quality Evaluation

	Image Quality Satisfaction	Cancerous lung nodule enhancement Satisfaction
Radiologist 1	87	91
Radiologist 2	88	95
Total percentage for Satisfaction	87.5	93

B. Objective Comparison

The objective evaluation was implemented in two phases. In phase, one the processed enhancement image is subtracted from the original image in order to test the enhancement percentage for the processed image as shown in Fig. 8. While in phase two, the subtraction was between the original image and LoG enhancement filter that used by the author [4].

The result, show that the proposed enhancement technique can enhancement the cancerous regions with 25% than the original image as shown in Fig. 8. Whereas, the LoG enhancement technique produce a zero value at the cancerous lung region as shown in Fig. 8. This means that the LoG enhancement method failed to enhance the cancerous regions in some CT image.



(A) Subtract Proposed Enhanced Image from Original Image

(B) Subtract LoG from Original Image

Fig. 8. Objective Evaluation

VI. CONCLUSION

The cancerous CT images are one of the problems that radiologist have in the diagnosis. The proposed enhancement CAD system can help the radiologist in the highlighting the suspicious lung regions. The algorithm is divided mainly into two stages, preprocessing and enhancement stages. In first stage, preprocessing the CT image was one of the challenges that I have in this paper. The accurate extraction for the lung regions is carried out using three steps. In the beginning, the noise filter is applied in order to remove any artifact or noise in the image. An adaptive thresholding algorithm is applied to the CT images then a morphological erosion process is applied. Finally, the lung extraction algorithm is implemented on all the CT images.

An adaptive local threshold algorithm is then used to enhance the cancerous lung nodule. The algorithm is design based on the visual characteristics for the tumor regions in the CT images.

The enhancement algorithm is evaluated using subjective and objective comparison. The proposed algorithm seems efficient to enhance the CT images based on the evaluation result.

ACKNOWLEDGMENT

The author is grateful to the Applied Science Private University, Amman, Jordan, for the full financial support granted to this research project.

REFERENCES

- [1] S Yamamoto, M Matsumoto, Y Tateno, T Inuma, T Matsumoto, "filter—a new filter based on mathematical morphology to extract the isolated shadow, and its application to automatic detection of lung cancer in X-ray CT". in Proc. 13th International Conference of Pattern Recognition, (1996), PP: 3–7.
- [2] LIDC lung nodule image database. National cancer imaging archive at <https://imaging.nci.nih.gov/ncia/>
- [3] Y Lee, Hara, H Fujita, S Itoh, T Ishigaki, "Automated detection of pulmonary nodules in helical CT images based on an improved template-matching technique". IEEE Trans. Med Imaging 20(7):595–604, (2001).
- [4] Zhenghao Shi, Jun Bai, Lifeng He, Tsuyoshi Nakamura, Quanzhu Yao, Hidenori Itoh "A Method for Enhancing Lung Nodules in Chest Radiographs by Use of LoGFilter", Image and Signal Processing CISP '09. 2nd International Congress, (2009) pp.1-4.
- [5] SK Shah, MF McNitt-Gray, SR Rogers, JG Goldin, RD Suh, JW Sayre JW, "Computer aided characterization of the solitary pulmonary nodule using volumetric and contrast enhancement features". Acad Radiol 12(10), PP:1310–1319, (2005).
- [6] A. A. AbuBaker, R.S.Qahwaji, Stan Ipson, Mohmmad H. Saleh, "One Scan Connected Component Labelling Technique", IEEE International Conference on Signal Processing and Communication, Dubai, United Arab Emirates, 2007, pp. 1283-1286.
- [7] Li W "Recent progress in computer-aided diagnosis of lung nodules on thin-section CT". Computer Med Imaging Graph 31(4–5), PP:248–257, (2007).
- [8] A. Chaudhary, S. Sukhraj Singh, "Lung Cancer Detection on CT Images By Using Image Processing", Computing Sciences (ICCS), International Conference pp.142-146, Sept.14-15, Phagwara, (2012).
- [9] Q Li, F Li, DoiK, "Computerized detection of lung nodules in thin-section CT images by use of selective enhancement filters and an automated rule-based classifier". Acad Radiol 15(2), PP:165–175, (2008).
- [10] J Pu, B Zheng, JK Leader, "An automated CT based lung nodule detection scheme using geometric analysis of signed distance field". Med Phys 35(8), PP:3453–3461, (2008).
- [11] S Matsumoto, Y Ohno, H Yamagata "Computer-aided detection of lung nodules on multidetector row computed tomography using three-dimensional analysis of nodule candidates and their surroundings". Radiat Med 26(9), PP:9–562, (2008).
- [12] B Sahiner, LM Hadjiiski, HP Chan, J Shi, PN Cascad, EA Kazerooni, "Effect of CAD on radiologists' detection of lung nodules on thoracic CT scans: observer performance study". Proc SPIE Med Imaging 6515(65151D), (2007), PP:1–7.
- [13] R Opfer, R Wiemker, "Performance analysis for computer aided lung nodule detection on LIDC data". Proc SPIE Med Imaging 6515(65151C), (2007), PP:1–9.
- [14] B Golosio, GL Masala, A Piccioli, P Oliva, M Carpinelli, "A novel multithreshold method for nodule detection in lung CT". Med Phys 36(8), (2009), PP:3607–3618.
- [15] T Messay, R Hardie, S Rogers, "A new computationally efficient CAD system for pulmonary nodule detection in CT imagery". Med Image Anal 14(3), (2010), PP:390–406.
- [16] RC Hardie, SK Rogers, T Wilson, A Rogers, "Performance analysis of a new computer aided detection system for identifying lung nodules on chest radiographs". Med Image Anal 12(3), (2008), PP:240–258
- [17] D Vivekanandan, S. Retmin Raj, "A Feature Extraction Model for Assessing the Growth of Lung Cancer in Computer Aided Diagnosis", IEEE-International Conference on Recent Trends in Information Technology, ICRTIT MIT, pp.953-958, (2011).
- [18] M. Dajnowicz, J. Alirezaie, "Computer Simulation for Segmentation of Lung Nodules in CT Images", Systems, Man and Cybernetics, IEEE International Conference, vol.5, (2004): PP:4491-4496.
- [19] J. Sousa, A. Silva, D. Paiva et al, "Methodology for automatic detection of lung nodules in computerized tomography images". Computer Methods Programs Biomed 98(1), (2010), PP:1–14
- [20] K. Devaki and V. MuraliBhaskaran, "Study of Computed Tomography Images of the Lungs", IEEE-International Conference on Recent Trends in Information Technology, ICRTIT MIT, Anna University, (2011), PP: 837-842.
- [21] A. Teramoto, H. Fujita, "Fast lung nodule detection in chest CT images using cylindrical nodule-enhancement filter", Int. Journal CARS, 8, (2013), PP:193–205
- [22] V. K. Likhitar, U Gawande, K. O. Hajari, "Automated Detection of Cancerous Lung Nodule from the Computed Tomography Images", IOSR Journal of Computer Engineering, 16(1), (2014), PP: 05-11.

AUTHOR PROFILE

Ayman A. Abubaker: he got his B.Sc. in Electrical Engineering on 1999. On 2008 he finished his PhD in Electronic Imaging and Media Communications (EIMC) from School of Informatics, University of Bradford-UK. He is an associate professor in processing and machine learning algorithms. His main research focused on processing medical images such as mammogram images (detecting microcalcifications and mass lesions), ultrasound images and MRI images. He is currently faculty of Engineering Vice Dean and Head of Electrical and Computer Engineering Dept., Applied Science Private University, Amman-Jordan.