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Detection of Pulmonary Nodule using Shape-Based Feature Descriptor and Neural Network

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Abstract. This research aims to detect the pulmonary nodule presented in lung Computed Tomography (CT) scan images. Generally, a Computer-Aided Diagnostic (CAD) system was designed and developed to aid the radiologists in medical imaging department to reduce the time and to obtain faster and better results for lung nodules diagnosis of a patient. Four major stages involve in this paper which are pre-processing, segmentation, features extraction and classification. The images that were utilized were acquired from LIDC-IDRI database that available publicly for CT scan lung images. Initially, the median filter was employed in pre-processing to filter and remove the noises, unwanted distortions and artifacts presented in the images during scanning process. For the second stage, the implementation of Otsu thresholding (thresholding-based method) and watershed algorithm (region-based method) were used to segment the nodules (Region of Interest (ROI)). Manual cropping method was implemented to segment the nodule for further process. The main contribution of this paper is the extraction of the features based on shape descriptor. 10 features were extracted from the segmented nodules. Finally, all extracted features from the segmented nodules were classified into nodule candidates and non-nodule candidates using Back Propagation Neural Network (BPNN). Based on the experiment, it can be observed that the proposed approach works well with CT scan images and segmented the interested nodules with the accuracy of 94%. This semi-automated approach is fast compared with the conventional approach used by the radiologists in current time being.

1. Introduction

Lung cancer is a disease of abnormal cells that develop in the area of lung. The lung cancer become the dominant cause of death among the other types of cancer. The estimation of the new cases of the lung cancer are higher and the number of death due to the lung cancer also increase for both sex; male and female in year 2017. The most common cancer that affected in men are prostate, lung, bronchus and colorectal cancer because it shows 42% out of all cases. For women, breast, lung, bronchus and colorectal cancer show about one-half of all cases present in 2017 [1].

Lung nodules do not always indicate as lung cancer. Additionally, the pulmonary nodules can either considered as cancerous or non-cancerous. A cancerous nodule is referred as malignant and a non-cancerous nodule is referred as benign. Benign tumor will not spread to the other parts of the body unless it agitates the function of the others organs or tissues and cause damage to it. On the other hand, the malignant is built up by cancer cells and it can spread to the nearby tissues by moving into the bloodstream or lymph nodes and it is known as metastasis [2]. Late detection of the pulmonary nodule can cause the delay in treatment and the cancer cells can only be detected at the advanced stage of the disease. Hence, for lung cancer diagnosis, the most effective way is to use the CT scan to detect the



pulmonary nodule due to its low cost, high quality, high sensitivity, high image resolution and details and robustness [3]. Therefore, the Computer-Aided Detection (CAD) system is introduced to assist the radiologist to evaluate the nodule in the CT images. It is proven that the CAD system improve the nodule detection and increase efficacy of the scanning [4]. The CAD system plays an important role in detection of cancer cells in the body as the system ease the work of the medical experts and radiologists.

2. Methodology

In this research, there are several stages including image acquisition, pre-processing of the lung CT images, segmentation, feature extraction and classification using neural network. Figure 1 shows the block diagram of the proposed approach.

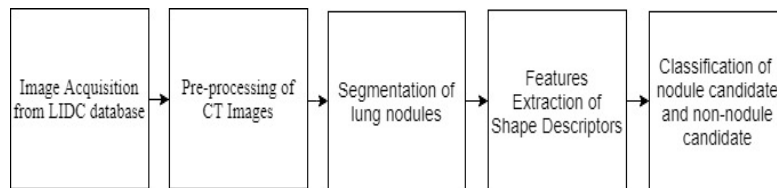


Figure 1. Block Diagram of the proposed system

2.1. Image Acquisition

LIDC-IDRI is the database in which the lung images are acquired for the input of this research. The images are in DICOM format. A total of 200 patients' slices are downloaded from this database for this work [5].

2.2. Pre-Processing Technique on Lung CT Slices

In this stage, the smoothing filtering was used to suppress the noises that present in the images. This smoothing process also blurred all sharp edges that was important information about the images. The noises that may present in the CT images include impulse noise, Gaussian noise and speckle noise. In this research, the median filter, average filter, min filter, max filter and Gaussian Filter were applied to the image to compare and find the best filtering method that can be implemented. The best filtering method was finalized and implemented on the images. The best method was selected based on the quality of the image produced after filtering process using three parameters: Mean Square Error (MSE), Peak Signal-to-Noise Ratio (PSNR) and Structural Similarity Index (SSIM) [6].

2.3. Segmentation of Lung Nodule

The filtered images were then undergo the segmentation process. The segmentation process is essential for segmenting the nodules from the lung CT scan images. The segmentation methods that implemented in this research were Otsu's thresholding and watershed transform. Otsu segmentation method is one of the global thresholding method [7]. It is a nonlinear operation and consecutively converts a grey-scale image into a binary image. Other than that, the watershed transform segmentation was used after using Otsu's thresholding for the images. Watershed segmentation is an edge based continuous domain segmentation method. Watershed is a ridge that splits areas drained by different river structures. A structural region that draining into a river or reservoir is known as catchment basins [8].

2.4. Shape-based Feature Extraction

The features extraction stage is used to extract the description of the nodule from the images after segmentation process. The nodules, non-nodules and background were found in the segmentation process. In this work, the features extraction was implemented using shape-based descriptor. The shape can be represented by moment, polygonal approximation, spatial interrelation feature and etc. These representations can be used for making measurements of the shape, matching shapes or for object recognition. The shape representation and specification techniques can be classified as in Figure 2:

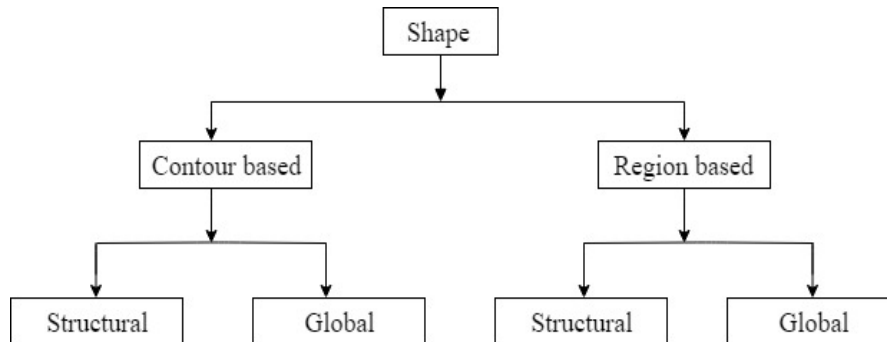


Figure 2. Classification of shape representation and specification techniques [9]

The classification of shape representation is divided into two categories which are contour based methods and region-based methods. Each method consists of two approaches, structural approach and global approach. Both of the approaches are related to a whole shape or segmented shape of the region of interest [9]. The region-based methods consist of geometric features and intensity features. The methods based on region computed all the pixels within the shape region compared to the method based on contour which it need extraction of boundary information [10]. The area, perimeter, major and minor axis length, eccentricity, solidity, centroid, equivalent diameter, circularity and convex area are categorized in region based shape representation and these parameters were extracted from the images to determine the shape of the nodule in the lung [10].

2.5. Neural Network Classification

A suitable neural network is necessary to efficiently determine the efficiency of the proposed system. Artificial neural network system (ANN) is a form of artificial intelligence system and classification method that is commonly used in image processing techniques. It is a collections of mathematical models that emulate the real neural structure of the human brain. This classification is essential for the radiologists to produce correct diagnosis result from the proposed system and necessary treatment can be imposed on the patients. Back Propagation Neural Network (BPNN) is a supervised algorithm of ANN [11].

3. Result & Discussion

3.1. Median Filtering

Pre-processing stage is crucial in any image processing processes as the images were incorporated with noises and any other forms of artifacts during the image acquisition process. Hence, there is a need to implement the filtering. The filtering techniques that had been applied on the images including Gaussian Filter, Median Filter, Average Filter, Min Filter, Max filter and Average filter. In this work several

images were used to test the suitable filtering method. Based on the result, it showed that median filter is the best filter that can be implemented on the lung CT scan. This is observed based on the PSNR result produced when compared to the other filtering methods. Table 1 shows the result in term of MSE, PSNR and SSIM for 3 x 3 windowing size. The MSE needs to be low meanwhile PSNR and SSIM need to be high in order to obtain the best filtered image. Based on the results, it can be seen that Median filter produces the best result when compared to min filter, max filter, average filter and Gaussian filter.

Table 1. Performance comparison on different filtering methods

Types of filter	MSE	PSNR	SSIM
Median filter	7.0723	39.6352	0.9539
Min filter	270.6243	23.8071	0.8423
Max filter	278.5906	23.6811	0.8436
Average filter	24.3175	34.2716	0.9408
Gaussian filter	3.6336	34.3955	0.9421

3.2. Lung CT Images Segmentation

After the pre-processing stage, the lung CT scan images undergo segmentation stage. Segmentation stage is important to segment the nodules from background. The extracted nodules will be the determinant factor for diagnosing the lung cancer among the potential patients. Through separation and difference in the threshold values between nodules, non-nodules, background and blood vessels, the objects which were having the same threshold value with the nodules were segmented. Initially, the image is segmented using Otsu thresholding as shown in Figure 3. It can be observed that, the nodules were segmented along with the boundary. Then, the resulting image after thresholding undergoes segmentation process once again using watershed segmentation. Watershed can segment the nodules as the watershed ridge lines produced by this method perfectly encapsulated the outer boundary of the nodules, non-nodules and background as shown in Figure 4. This result supported by the theory that watershed segmentation uses the ridge lines and catchment basis principles in segmenting the objects from background. Figure 5 shows the sample segmentation results comparing with the ground truth image.

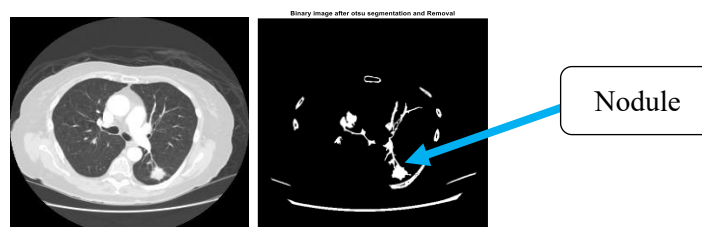


Figure 3. (a) Original image (b) Binary image after Otsu thresholding

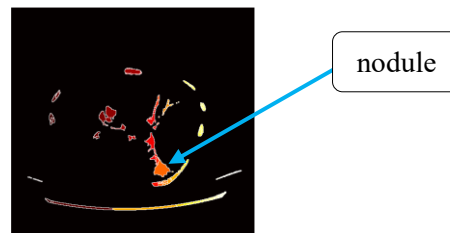


Figure 4. Watershed segmentation

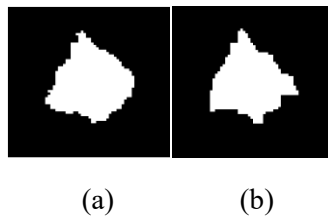


Figure 5. (a) ground truth image from LIDC-IDRI database (b) segmented image using watershed

The performance of the segmented nodules can be measured by calculating the sensitivity, specificity and accuracy. This can be done using the ground truth image and the segmented result from watershed segmentation.

3.3. Extraction of Shape-based Features on Lung Nodule

The third major stage in this project is features extraction stage. After manual cropping process, the important features of the cropped nodule were extracted. The features that were extracted from the cropped nodule included area, centroid, major axis length, minor axis length, eccentricity, convex area, equivalent diameter, solidity, perimeter and circularity. These 10 features determined the development of that particular nodules in subsequent scanning. During the first scanning, all the values of these 10 features were examined and recorded. In subsequent scanning, if any of these important features indicated increment, there indicated the higher probability of developing lung cancer on that patients. Besides, the features that were extracted were important as being the input to the classifier.

3.4. Classification of Lung Nodule Candidate and Non-Nodule Candidate

Next, the extracted features were given to the classifier. The classifier being used in this project was Back Propagation Neural Network (BPNN). The algorithm that was used for classifier was Levenberg-Marquart algorithm, with 10 input features for 200 samples, 12 hidden layers and two output data. The output was set such that the segmented objects were being nodules and non-nodules. The proportion of training and testing were set to 80/20. Three default values were set after the division of data into testing and training stage. The three default parameters were show, epochs and goal, which were set to 10, 200 and 0.5e-2 respectively. The goal parameter is usually the default setting parameter. The epochs value indicates the number of iterations that the system should be reached before the training and testing of data ends. Next, the neural network was trained and the system was simulated. The network was tested after the previous process. After the network has been trained, one could use it to compute the network outputs. Finally, the calculation of sensitivity, specificity and accuracy could be done by using the confusion matrix obtained from the network. The errors and overall performance of the system was calculated.

All Confusion Matrix

		1	2	
Output Class	1	96 48.0%	8 4.0%	92.9%
	2	4 2.0%	92 46.0%	95.8%
		96.0%	92.0%	94.0%
		4.0%	8.0%	6.0%
		1	2	
		Target Class		

Figure 6. Confusion matrix

From the above confusion matrix as shown in Figure 6, it can be learnt that the overall accuracy of this project is 94% with error at 6%. This accuracy level obtained shows that that the proposed system could detect the segmented objects as nodules at an accuracy level of 94% and minimum error of 6%.
Conclusion

This work can assist the radiologist or imaging department of current hospital systems to diagnose the lung cancer. The increment in the major features of the cropped nodules such as circularity, area, perimeter and minor axis length during subsequent scanning can indicate the development of the nodules. The development or increment in the features of the nodule indicate the high possibility of lung cancer on the patients. Therefore, early detection of this cancerous development could be conducted and this will improve the life quality of the patients.

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