Detection of nodules and end-on blood vessels in CT scan image of Lungs

TN Ramdeep
M. Tech Student, Dept. of ECE
JNTUH College of Engineering, Hyderabad
ramdeeptn@gmail.com

M. Sampath
Lecturer, Dept. of ECE
JNTUH College of Engineering, Hyderabad
sampathmankena@gmail.com

Dr. T. Satya Savithri
Professor& Head, Dept. of ECE
JNTUH College of Engineering, Hyderabad
tirumalasatya@jntuh.ac.in

***Abstract*—Most significant issue in lung cancer treatment is early detection of pulmonary nodules. Most of the times, detection of nodules are confused with blood vessels and more false positives are obtained. Hence there is a need of detection of nodules and end on blood vessels separately. This problem is addressed in this paper. From CT scan images suspected regions are identified using segmentation. Classifiers are used to classify nodules. In this paper two segmentation techniques: Thresholding and Region growing along with three classifiers SVM, ANN, CNN are presented and the performance comparison of each segmentation technique along with a classifier is given.**

Keywords: Thresholding, Region Growing, SVM, ANN, CNN

1. Introduction

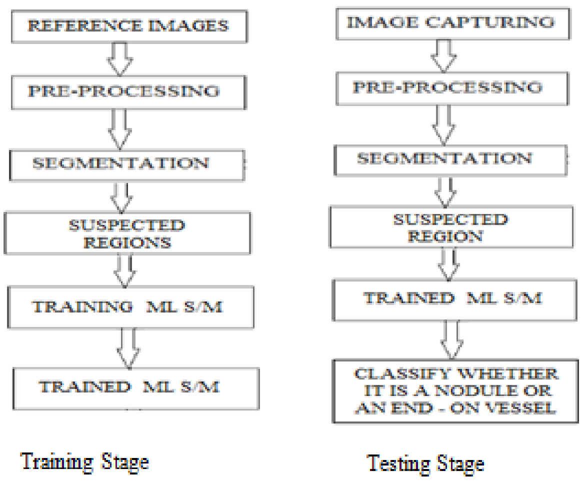
Lung cancer is one of the dominant causes of deaths related to cancer therefore it is very important to detect the cancer as early as possible. Small round shaped legions called as pulmonary nodules are the earliest stage of the lung cancer. Therefore being able to identify these nodules has become the most important task for diagnosing the lung cancer in the early stages. X-Ray, Computer Tomography (CT) scans and Magnetic Resonance Imaging (MRI) are used for capturing images. Among these CT scan is effective and captures images in various angles around human body. An automated or semi automated methods are required to process large data obtained from CT images. Computer Aided Diagnosis (CAD) are developed to assist the physicians in the detection of abnormalities, quantification of disease progress and differential diagnosis of various lesions.

Now a days there are many CAD tools available for detecting (segmenting) the nodule in CT image of a lung. But however, they generate many false positives, which make the CAD system inefficient. The inability of CAD system to properly differentiate between a nodule and an end-on vessel is one of the major reasons for the number of false positives.

The objective of this paper is to successfully classify nodule and end-on blood vessel in a CT image using the machine learning techniques like Support Vector Machine (SVM) and Convolution Neural Network (CNN) and compare their performance. The objectives of proposed algorithm in this paper are

- To enhance the CT images using pre-processing techniques and apply segmentation algorithms to detect the suspected regions.
- To design and train the Machine Learning Algorithm using the reference CT images.
- To classify (test) whether the suspected region in CT image is a nodule or an end-on vessel by using the trained Machine Learning Algorithm.

Flow chart of proposed algorithm is shown below:



The main aim of image pre-processing is to enhance the quality of data through denoising (application of mean filters, median filters, Laplacian filters and Gaussian filters), enhancing the edges of image structures (unsharping, wavelet transform), and improving image contrast (histogram equalization).

Segmentation divides an image into regions. Segmentation has to be done until the objects of interest in an application are isolated. Segmentation algorithms use two basic properties of intensity values: discontinuity, partition of image when intensity changes abruptly and similarity, partition of image which satisfies some predefined criteria. Some of such algorithms are Thresholding, region growing, and region splitting and merging. By Segmenting the image suspected regions are found and classification techniques (SVM, CNN) applied to classify nodule and vessels.

2. Pre Processing

The CT image is first converted into gray level image and is enhanced by sharpening and contrast adjustment. The required binary images are obtained by processing the image using otsu thresholding on histogram of image.

Otsu method is a global thresholding in which gray values of the image are used. This method is based on discriminate analysis. The threshold operation is regarded as the partitioning of the pixels of an image into two classes C0 and C1 (e.g., objects and background) at grey-level t, i.e., C0 = {0, 1, 2,…, t} and C1 = {t + 1, t +2,….L-1}. As stated in [11], let σ^2_w, σ^2_b and σ^2_t be the within-class variance, between-class variance, and the total variance, respectively. An optimal threshold can be determined by minimizing one of the following (equivalent) criterion functions with respect to t:

$$\lambda = \frac{\sigma_B^2}{\sigma_W^2},\quad \eta = \frac{\sigma_B^2}{\sigma_T^2},\quad \kappa = \frac{\sigma_T^2}{\sigma_W^2}$$

The above three criterion functions, η are the simplest. Thus, the optimal threshold t is defined as t = Arg Min ηwhere

$$\sigma_T^2 = \sum_{i=0}^{L-1}[1-\mu_T]^2 P_i\ ,\ \mu_T = \sum_{i=0}^{L-1}[iP_i]$$

$$\sigma_B^2 = W_0 W_1(\mu_0\mu_1)^2\ ,\ W_0 = \sum_{i=0}^{t} P_i\ ,\quad W_1 = 1 - W_0$$

$$\mu_1 = \frac{\mu_T - \mu_t}{1 - w_0},\quad \mu_0 = \frac{\mu_t}{W_0}\quad ,\mu_t = \sum_{i=0}^{t}(iP_i)$$

$$P_i = \frac{n_i}{n}$$

Where n_i is the number of pixels with grey-level i and n is the total number of pixels in a given image defined as

$$n = \sum_{i=0}^{L-1} n_i$$

Moreover, Pi is the probability of occurrence of grey-level i. Otsu's method as proposed affords further means to analyze further aspects other than the selection of the optimal threshold for a given image. For a selected threshold t_ of a given image, the class probabilities w0 and w1 indicate the portions of the areas occupied by the classes C0 and C1. The class means µ0 and µ1 serve as estimates of the mean levels of the classes in the original grey-level image.

3. Segmentation

Thresholding and region growing are used for segmentation. Thresholding uses gray level distribution of image to separate regions of interest based on some threshold gray level. .If g(x, y) is a threshold version of f(x, y) at some global threshold *T*, it can be defined as, g(x, y) = 1 if f(x, y) ≥ T, g(x, y) = 0 otherwise.

Region growing segmentation starts with selection of seed points and threshold. Then compare each seed point(s) with its neighbor pixel(x). The neighbor pixel x is added to seed point region if x is similar to seed point or the difference between s and x is less than threshold. This can be continued to all pixels to form coherent regions. Seed point is selected from the enhanced image.

4. Classification

In this paper SVM and CNN classifiers are used. A Support Vector Machine (SVM) is a classifier defined by a separating hyper plane. SVM operation depends on finding a hyper plane that gives maximum margin of training samples. A hyper plane is denoted by expression $f(x) = \beta_0 + \beta^T x$, where β is *weight vector* and β_0 is *bias.* Hyper plane can be represented in infinite ways; among all $|\beta_0 + \beta^T x| = 1$ is chosen, where x represents the training data close to hyper plane.

The idea behind Artificial Neural Networks is human brain. ANNs have multiple nodes connected by links similar to neurons of human brain which interacts. Nodes will take data input, processes data and passes to other nodes. Each nodes output is called as activation or node value. Each link has a weight, which can be modified making ANNs capable of learning.

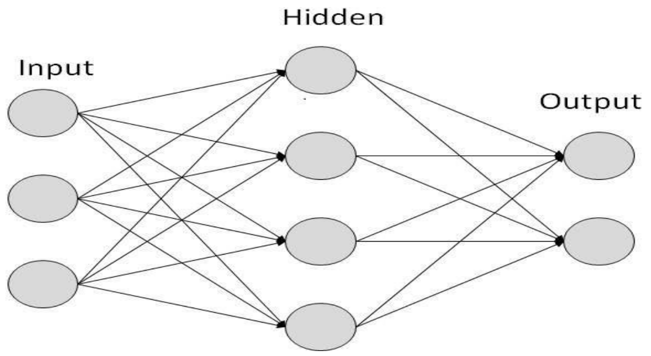


Fig: 4.1. ANN Network

ANNs use two topologies Feed Forward and Feedback. In Feed Forward ANN information flow is unidirectional. Feedback is used in Feedback ANN. ANNs work by altering weights associated with each link. If network output is good weight remains same. If it is bad weight is altered to improve result. Back propagation is used to optimize weights.

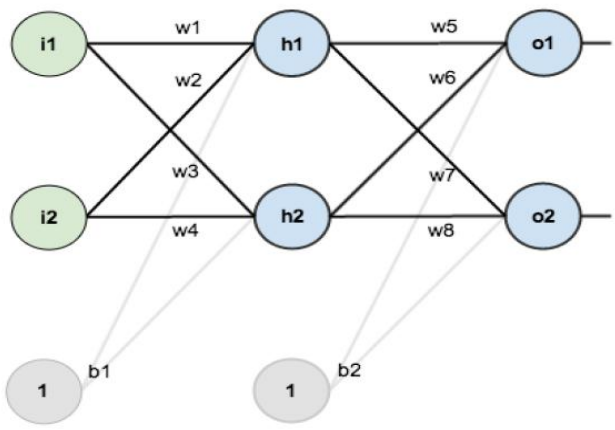


Fig: 4.2. ANN Network with weights

The total net input to each hidden layer neuron is calculated, squash the total net input using an activation function (the logistic function), and repeat the process with the output layer neurons. Total net input for 'h1is $net_{h1}=w_1*i_1+w^2*i_2+b_1*1$, we then squash it using the logistic function to get the output of 'h1': $out_{h1}=1/(1+e^{-net}{}_{h1})$.The output for 'o1, $net_{o1}=w_5*out_{h1}+w_6*out_{h2}+b_2*1$. Carry the process to get o2.We can now calculate the error for each output neuron using the squared error function and sum them to get the total error $E_{total}=\sum 1/2(\text{target-output})^2$. Repeat the process for o2.The total error for the neural network is the sum of these errors $E(\text{total})=E_{o1}+E_{o2}$.

Convolutional Neural Networks (CNN) has neurons arranged in 3 dimensions: **width, height, depth.** A CNN is formed by series of layers. A differentiable function is used to transform output of one layer to other. Mainly three layers are used to build a CNN, **Convolutional Layer, Pooling Layer,** and **Fully-Connected Layer**. Convolutional layer is building block of CNN, which contain learnable filters. It calculates output of neurons connected to local regions in the input. The pooling layer is inserted between convolutional layers. It is used to reduce size to reduce computations. The fully connected layer is similar to ANN.

5. Results

The experimental results are presented here. The suspected regions are identified after segmenting the image, after classification nodules and end-on blood vessels are detected. Some of the obtained images are shown below. Fig. 5.1 shows data base of CT scan image of lungs with blood vessels and nodules. Resultant suspected regions after pre processing and segmentation are shown in Fig 5.2. Fig 5.3 shows the classification of nodule and end-on blood vessels from suspected regions using CNN classifier. Fig 5.4 shows the detection of nodules or blood vessel on original CT scan image using SVM classifier. Comparison of all the techniques with different segmentation and classification are shown in Fig 5.5 to Fig 5.9.

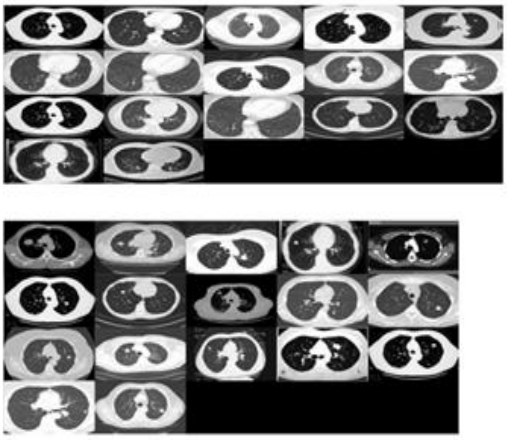


Fig: 5.1. Database of CT images containing Blood vessel(top) and Nodules(bottom)

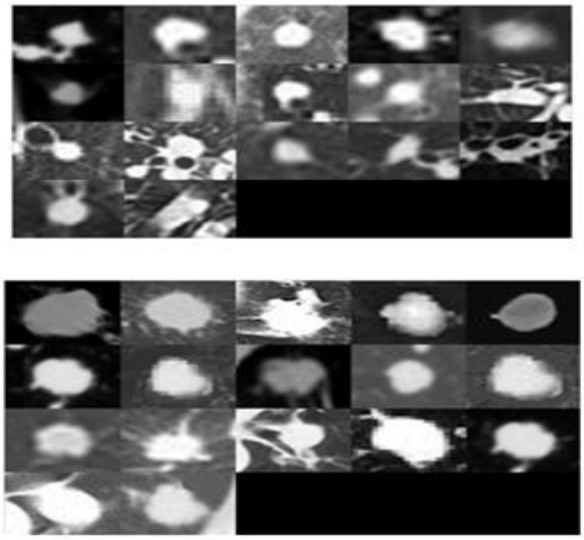
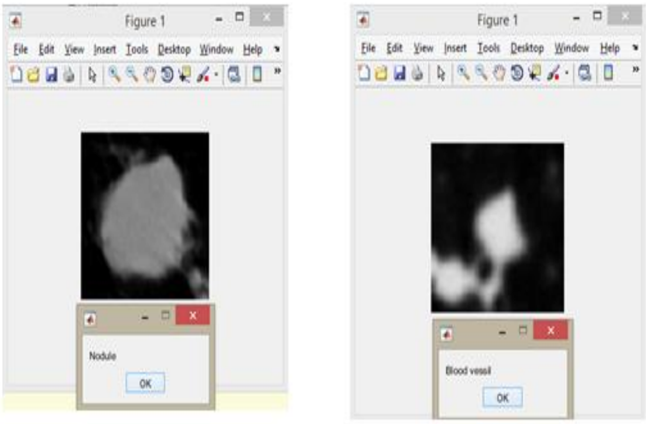


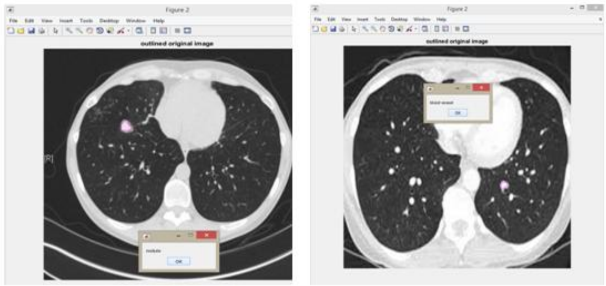
Fig: 5.2.Suspected regions of blood Vessel (top) Suspected regions of Nodules (bottom)



CNN classifier classifying a Nodule

CNN classifier classifying a Blood Vessel

Fig: 5.3. CNN classifier classifying nodule and blood vessel



SVM classifier classifying a Nodule

SVM classifier classifying a Blood Vessel

Fig: 5.4. SVM classifier classifying nodule and blood vessel

SEGMENTATION = THRESHOLDING CLASSIFICATION = SVM

With two properties				With three properties				With four properties			
Input	Type	Output	Conclusion	Input	Type	Output	Conclusion	Input	Type	Output	Conclusion
b_01	B	B	0	b_01	B	B	0	b_01	B	B	0
b_02	B	B	0	b_02	B	B	0	b_02	B	B	0
b_03	B	B	0	b_03	B	B	0	b_03	B	B	0
b_04	B	B	0	b_04	B	B	0	b_04	B	N	1
b_05	B	B	0	b_05	B	B	0	b_05	B	B	0
b_06	B	B	0	b_06	B	B	0	b_06	B	B	0
b_07	B	N	1	b_07	B	B	0	b_07	B	B	0
b_08	B	N	1	b_08	B	N	1	b_08	B	B	0
b_09	B	B	0	b_09	B	B	0	b_09	B	B	0
b_10	B	B	0	b_10	B	B	0	b_10	B	B	0
b_11	B	B	0	b_11	B	B	0	b_11	B	B	0
b_12	B	B	0	b_12	B	B	0	b_12	B	B	0
b_13	B	B	0	b_13	B	B	0	b_13	B	B	0
b_14	B	B	0	b_14	B	B	0	b_14	B	B	0
b_15	B	B	0	b_15	B	B	0	b_15	B	B	0
b_16	B	B	0	b_16	B	B	0	b_16	B	B	0
b_17	B	B	0	b_17	B	B	0	b_17	B	B	0
b_18	B	N	1	b_18	B	B	0	b_18	B	B	0
n_01	N	N	0	n_01	N	N	0	n_01	N	N	0
n_02	N	N	0	n_02	N	N	0	n_02	N	N	0
n_03	N	N	0	n_03	N	N	0	n_03	N	N	0
n_04	N	N	0	n_04	N	N	0	n_04	N	N	0
n_05	N	N	0	n_05	N	N	0	n_05	N	N	0
n_06	N	N	0	n_06	N	N	0	n_06	N	N	0
n_07	N	N	0	n_07	N	N	0	n_07	N	N	0
n_08	N	N	0	n_08	N	N	0	n_08	N	N	0
n_09	N	B	1	n_09	N	B	1	n_09	N	B	1
n_10	N	B	1	n_10	N	B	1	n_10	N	B	1
n_11	N	B	1	n_11	N	B	1	n_11	N	N	0
n_12	N	N	0	n_12	N	N	0	n_12	N	N	0
n_13	N	N	0	n_13	N	N	0	n_13	N	N	0
n_14	N	N	0	n_14	N	N	0	n_14	N	N	0
n_15	N	N	0	n_15	N	N	0	n_15	N	N	0
n_16	N	N	0	n_16	N	N	0	n_16	N	N	0
n_17	N	B	1	n_17	N	B	1	n_17	N	N	0
No. of errors =			7	No. of errors =			5	No. of errors =			3
Error % =			20	Error % =			14.286	Error % =			8.5714

True Positives: 41 False Positive: 10

True Negative: 49 False Negative: 5

Fig: 5.5. SVM with Thresholding

SEGMENTATION = Region Growing CLASSIFICATION = SVM

With two properties				With three properties				With four properties			
Input	Type	Output	Conclusion	Input	Type	Output	Conclusion	Input	Type	Output	Conclusion
b_01	B	N	1	b_01	B	N	1	b_01	B	B	0
b_02	B	B	0	b_02	B	B	0	b_02	B	B	0
b_03	B	B	0	b_03	B	B	0	b_03	B	B	0
b_04	B	B	0	b_04	B	B	0	b_04	B	B	0
b_05	B	B	0	b_05	B	B	0	b_05	B	B	0
b_06	B	B	0	b_06	B	B	0	b_06	B	B	0
b_07	B	B	0	b_07	B	B	0	b_07	B	B	0
b_08	B	B	0	b_08	B	B	0	b_08	B	B	0
b_09	B	B	0	b_09	B	B	0	b_09	B	B	0
b_10	B	B	0	b_10	B	B	0	b_10	B	B	0
b_11	B	B	0	b_11	B	B	0	b_11	B	B	0
b_12	B	B	0	b_12	B	B	0	b_12	B	B	0
b_13	B	B	0	b_13	B	B	0	b_13	B	B	0
b_14	B	B	0	b_14	B	B	0	b_14	B	B	0
b_15	B	B	0	b_15	B	B	0	b_15	B	B	0
b_16	B	B	0	b_16	B	B	0	b_16	B	B	0
b_17	B	B	0	b_17	B	B	0	b_17	B	B	0
b_18	B	B	0	b_18	B	B	0	b_18	B	B	0
n_01	N	B	1	n_01	N	B	1	n_01	N	B	1
n_02	N	N	0	n_02	N	N	0	n_02	N	N	0
n_03	N	N	0	n_03	N	N	0	n_03	N	N	0
n_04	N	N	0	n_04	N	N	0	n_04	N	N	0
n_05	N	N	0	n_05	N	N	0	n_05	N	N	0
n_06	N	N	0	n_06	N	N	0	n_06	N	N	0
n_07	N	N	0	n_07	N	N	0	n_07	N	N	0
n_08	N	N	0	n_08	N	N	0	n_08	N	N	0
n_09	N	N	0	n_09	N	N	0	n_09	N	N	0
n_10	N	N	0	n_10	N	N	0	n_10	N	N	0
n_11	N	N	0	n_11	N	N	0	n_11	N	N	0
n_12	N	N	0	n_12	N	N	0	n_12	N	N	0
n_13	N	N	0	n_13	N	N	0	n_13	N	N	0
n_14	N	N	0	n_14	N	N	0	n_14	N	N	0
n_15	N	N	0	n_15	N	N	0	n_15	N	N	0
n_16	N	N	0	n_16	N	N	0	n_16	N	N	0
n_17	N	N	0	n_17	N	N	0	n_17	N	N	0
No. of errors =			2	No. of errors =			2	No. of errors =			1
Error % =			5.7143	Error % =			5.7143	Error % =			2.8571

True Positives: 48 False Positive: 3

True Negative: 52 False Negative: 2

Fig: 5.6. SVM with Region Growing

SEGMENTATION = THRESHOLDING CLASSIFICATION = ANN

With two properties

Input	Type	Output	Conclusion
b_01	B	B	0
b_02	B	B	0
b_03	B	B	0
b_04	B	B	0
b_05	B	B	0
b_06	B	N	1
b_07	B	N	1
b_08	B	B	0
b_09	B	B	0
b_10	B	B	0
b_11	B	B	0
b_12	B	B	0
b_13	B	B	0
b_14	B	B	0
b_15	B	N	1
b_16	B	B	0
b_17	B	B	0
b_18	B	B	0
n_01	N	N	0
n_02	N	N	0
n_03	N	N	0
n_04	N	N	0
n_05	N	N	0
n_06	N	N	0
n_07	N	N	0
n_08	N	N	0
n_09	N	N	0
n_10	N	B	1
n_11	N	N	0
n_12	N	N	0
n_13	N	N	0
n_14	N	B	1
n_15	N	N	0
n_16	N	N	0
n_17	N	B	1
No. of errors =			6
Error % =			17.143

With three properties

Input	Type	Output	Conclusion
b_01	B	B	0
b_02	B	B	0
b_03	B	B	0
b_04	B	B	0
b_05	B	B	0
b_06	B	B	0
b_07	B	N	1
b_08	B	B	0
b_09	B	B	0
b_10	B	B	0
b_11	B	B	0
b_12	B	B	0
b_13	B	B	0
b_14	B	B	0
b_15	B	B	0
b_16	B	B	0
b_17	B	B	0
b_18	B	B	0
n_01	N	N	0
n_02	N	N	0
n_03	N	N	0
n_04	N	N	0
n_05	N	N	0
n_06	N	N	0
n_07	N	N	0
n_08	N	N	0
n_09	N	N	0
n_10	N	B	1
n_11	N	N	0
n_12	N	N	0
n_13	N	B	1
n_14	N	N	0
n_15	N	N	0
n_16	N	N	0
n_17	N	N	0
No. of errors =			3
Error % =			8.5714

With four properties

Input	Type	Output	Conclusion
b_01	B	B	0
b_02	B	B	0
b_03	B	B	0
b_04	B	N	1
b_05	B	B	0
b_06	B	B	0
b_07	B	B	0
b_08	B	B	0
b_09	B	B	0
b_10	B	B	0
b_11	B	B	0
b_12	B	B	0
b_13	B	B	0
b_14	B	B	0
b_15	B	B	0
b_16	B	B	0
b_17	B	N	1
b_18	B	B	0
n_01	N	N	0
n_02	N	N	0
n_03	N	N	0
n_04	N	N	0
n_05	N	N	0
n_06	N	N	0
n_07	N	N	0
n_08	N	N	0
n_09	N	N	0
n_10	N	N	0
n_11	N	N	0
n_12	N	B	1
n_13	N	N	0
n_14	N	N	0
n_15	N	N	0
n_16	N	N	0
n_17	N	N	0
No. of errors =			3
Error % =			8.5714

True Positives: 45 False Positive: 6

True Negative: 48 False Negative: 6

Fig: 5.7. ANN with Thresholding

SEGMENTATION = Region Growing CLASSIFICATION = ANN

With two properties

Input	Type	Output	Conclusion
b_01	B	N	1
b_02	B	B	0
b_03	B	B	0
b_04	B	B	0
b_05	B	B	0
b_06	B	B	0
b_07	B	B	0
b_08	B	B	0
b_09	B	N	1
b_10	B	B	0
b_11	B	B	0
b_12	B	N	1
b_13	B	B	0
b_14	B	B	0
b_15	B	B	0
b_16	B	B	0
b_17	B	B	0
b_18	B	B	0
n_01	N	N	0
n_02	N	N	0
n_03	N	N	0
n_04	N	N	0
n_05	N	N	0
n_06	N	B	1
n_07	N	N	0
n_08	N	N	0
n_09	N	N	0
n_10	N	N	0
n_11	N	N	0
n_12	N	N	0
n_13	N	N	0
n_14	N	N	0
n_15	N	N	0
n_16	N	N	0
n_17	N	N	0
No. of errors =			4
Error % =			11.429

With three properties

Input	Type	Output	Conclusion
b_01	B	N	1
b_02	B	B	0
b_03	B	B	0
b_04	B	B	0
b_05	B	B	0
b_06	B	B	0
b_07	B	B	0
b_08	B	B	0
b_09	B	B	0
b_10	B	B	0
b_11	B	B	0
b_12	B	N	1
b_13	B	B	0
b_14	B	B	0
b_15	B	B	0
b_16	B	B	0
b_17	B	B	0
b_18	B	B	0
n_01	N	N	0
n_02	N	N	0
n_03	N	N	0
n_04	N	N	0
n_05	N	N	0
n_06	N	N	0
n_07	N	N	0
n_08	N	N	0
n_09	N	N	0
n_10	N	N	0
n_11	N	N	0
n_12	N	N	0
n_13	N	N	0
n_14	N	N	0
n_15	N	N	0
n_16	N	N	0
n_17	N	N	0
No. of errors =			2
Error % =			5.7143

With four properties

Input	Type	Output	Conclusion
b_01	B	B	0
b_02	B	B	0
b_03	B	B	0
b_04	B	B	0
b_05	B	B	0
b_06	B	B	0
b_07	B	B	0
b_08	B	B	0
b_09	B	N	1
b_10	B	B	0
b_11	B	B	0
b_12	B	N	1
b_13	B	B	0
b_14	B	B	0
b_15	B	B	0
b_16	B	B	0
b_17	B	B	0
b_18	B	B	0
n_01	N	N	0
n_02	N	N	0
n_03	N	N	0
n_04	N	N	0
n_05	N	N	0
n_06	N	N	0
n_07	N	N	0
n_08	N	N	0
n_09	N	N	0
n_10	N	N	0
n_11	N	N	0
n_12	N	N	0
n_13	N	N	0
n_14	N	N	0
n_15	N	N	0
n_16	N	N	0
n_17	N	N	0
No. of errors =			2
Error % =			5.7143

True Positives: 50 False Positive: 1

True Negative: 47 False Negative: 7

Fig: 5.8. ANN with Region Growing

SEGMENTATION = Region Growing CLASSIFICATION = CNN

Input	Type	Output	Conclusion
b_01	B	B	0
b_02	B	N	1
b_03	B	B	0
b_04	B	N	1
b_05	B	B	0
b_06	B	B	0
b_07	B	B	0
b_08	B	B	0
b_09	B	N	1
b_10	B	N	1
b_11	B	N	1
b_12	B	B	0
b_13	B	B	0
b_14	B	N	1
b_15	B	B	0
b_16	B	B	0
b_17	B	B	0
n_01	N	N	0
n_02	N	N	0
n_03	N	N	0
n_04	N	N	0
n_05	N	N	0
n_06	N	N	0
n_07	N	N	0
n_08	N	N	0
n_09	N	N	0
n_10	N	N	0
n_11	N	N	0
n_12	N	N	0
n_13	N	B	1
n_14	N	N	0
n_15	N	N	0
n_16	N	B	1
n_17	N	B	1
No. of errors =			9
Error % =			26.4706

True Positives: 14 False Positive: 3

True Negative: 12 False Negative: 6

Fig: 5.9. CNN with Region Growing

The percentage of error is shown table 5.1 for combination of each segmentation technique and classifier used.

SEGMENTATION	CLASSIFICATION	Error Percentage		
No. of Features		2	3	4
THRESHOLDING	SVM	20	14.286	8.5714
REGION GROWING	SVM	5.714	5.714	2.857
THRESHOLDING	ANN	17.143	8.571	8.571
REGION GROWING	ANN	11.429	5.714	5.714
REGION GROWING	CNN	26.471		

Table.5.1. Comparison of SVM, ANN, CNN

6. Conclusion

For the classification of nodules and blood vessels in CT scan of lungs, two segmentation techniques and three classifiers are proposed. Among of segmentation methods region growing technique presents more accurate results compare to thresholding technique. But the selection of seed point is very difficult in region growing method. Among of classifiers SVM is the best method compared to ANN and CNN. The output of ANN and CNN classifies base on the neural network approach. The output of ANN and CNN classifier depends on the weights associated with each link in the network, in order to obtain the appropriate weights for the network, the system should have more number of iterations or weight updates during training stage. Therefore ANN and CNN requires more input data to get more accurate output, but where as in the SVM, even for a less input data the accuracy will be high. SVM classifier has a better performance when there is a limited input data, but for a large input data ANN and CNN classifiers has an upper hand compared to SVM.

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