Kohonen Neural Network
For
Image Classification

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Abstract:

The medical image processing technique for diagnosis an important diseases considers very important for human's live .This research in troduce a system that is able to diagnose cancer diseases for lung in both normal and abnormal states for the (Computerized Tomography) CT-scan and (Magnetic Resonance) MRI images. This system includes two stages to get the right diagnosis ; Both of the two stages include are divided in to sub systems ; the first stage contains the digital image processing stage (preprocessing). This stage consists of enhancement and edge detection system by the convolution of smooth and sharp filters on image after that image analysis system is used for the extraction of features matrix which consists of histogram and moments features .The second stage is the classification stage that input all coefficients which result from the analysis stage to Kohonen neural network to make the decision .The system has been implemented on two classes of the medical images .The results showed the success of the classification of Kohonen neural in the classification stage for most the input images .

شبكة كوهنين العصبية لتصنيف الصورة

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الخلاصة

تعتبر تقنية معالجة الصور الطبية مهمة جدا في حياة الإنسان وذلك لاستخدامها في تشخيص الإمراض. يعرض هذا البحث النظام الذي يستعمل في تشخيص إمراض سرطان الرئة اذ يشخص الحالة الطبيعية والحالة الغير طبيعية (الإصابة بالسرطان) لعضو الرئة في جسم الإنسان بوساطة أشعة الـ(Computerized Tomography (Ct-scan و (Magnetic Resonance (MRI. يتضمن هذا النظام مرحلتين للتوصل إلى التشخيص الصحيح وكلا المرحلتين تنقسم إلى أنظمة جزئية . تحتوي المرحلة الأولى مرحلة معالجة الصورة الرقمية (معالجة مسبقة

)، وتتألف هذه المرحلة من نظام التحسين ونظام تحديد الحافة بوساطة تسليط فلاتر التنعيم وفلاتر الحدة على الصورة , بعد ذلك استخدام نظام تحليل الصورة لأجل استخلاص مصفوفة من المعاملات التي تتألف من معاملات
(moments features, histogram). المرحلة الثانية هي مرحلة تصنيف الصورة التي تستخدم المعاملات الناتجة من عملية التحليل كإدخالات لشبكة كوهنين العصبية لأجل اتخاذ القرار.
نفذ النظام على اثنين من الصور الطبية الحالة الطبيعية والحالة غير الطبيعية (الإصابة بالسرطان) لعضو الرئة وأثبتت النتائج نجاح شبكة كوهنين في تصنيف الصور الطبية المدخلة .

1. Introduction

The cancer tumor is one of the most common deadly diseases in the world [1]. Detection of that tumor exists by known medical tools such as, (magnetic resonance images) MRI , X-RAY films, (computerized tomography imaging) CT-scan produces high resolution images where pixel intensity is interpreted as tissue density [2]. Digital image processing is an ever expanding and dynamic area with applications reaching out into our everyday life such as in medicine, space exploration, surveillance, authentication, automated industry inspection , and in many other areas. Applications such as these involve different processes like image enhancement, object detection, image processing system which consists of a source of image data, a processing element and destination for the processed results. The source of image data may be a camera , a scanner, mathematical equation or statistical data [3] .

During the last decades, along with the rapid developments of image processing and pattern recognition techniques , computer-aided tumors diagnosis attracts more and more attention [1].Many achievements converted the medical images to format of digital images with classification mechanism to describe an image based on metadata such as histograms ,texture , or shape features to provide an accurate description of an image based on the image’s content using a neural networks to classify images and identify the tumors [4] .

An artificial neural networks is an information –processing system that has certain performance characteristics in common with biological neural networks .Artificial neural networks have been developed as generalizations of mathematical models of human cognition or neural biology based on the assumptions that :

1. Information processing occurs in many simple elements called neurons .
2. Signals are passed between neurons over connection links.

3. Each connection link has an associated weight in typical neural net multiplies the signal transmitted.
4. Each neuron applies activation function (usually nonlinear) to its net input (sum of weight input signals) to determine its output signal function of neural networks .

The neural net is used in (Control , Pattern Recognition, Medicine, Speech recognition and Business). Types architectures of neural networks are :single-layer net, multilayer net and competitive layer [5] .

Neural network is proved to be useful in application ranging from medical imaging processing. The network takes an image as input and gives it a classification as an output. .One of the types of neural networks is competitive learning neural networks which have been used successfully to train supervised mode which has pre-defined output categories [6] .It can be used to classify a set of patterns in Kohonen neural network where the number of features detectors and the number of iterations used to train the network were determined from experimental results . One output node was chosen for this network. In this study, the models are extended in Kohonen neural network for images classification for CT and MRI to diagnose the cancer tumors in a part of human body such as lung , and discover it in early stage for early treatment ; the output of the image analysis and features extraction stage is regarded as an input to the net.The research aims to design a system combining image processing with neural network to provide the detection to the normal and abnormal states and to locate tumor into CT-scan , MRI . The system runs in two stages : image processing and image classification .The first stage may pass several systems to get the best result for example the proposed system begin with images acquisition operation and image enhancement system which includes the application of smoothing filters (Mean, Median) on an image to remove the noise and blurring . The edge detection operation of image is then used to perform segmentation technique , edge detection operation , is chosen by using sharpening filters (Laplacian ,Robert ,Sobel).The analysis operation of the image is used to generate the features such as histogram and moments where the parameters result from analysis operation are used as inputs Kohonen neural network to diagnose the tumor. Supervised and learning vector quantization algorithm LVQ are the learning rules that used to train the network , where the decision of the network is either normal or abnormal and tumor is located .

The proposed system .2

The proposed system diagnoses the tumors and their location in the lungs by using medical CT-scan images with two states for each (normal and abnormal).
The following block diagram state the practical stages of proposed system shown in figure (1).

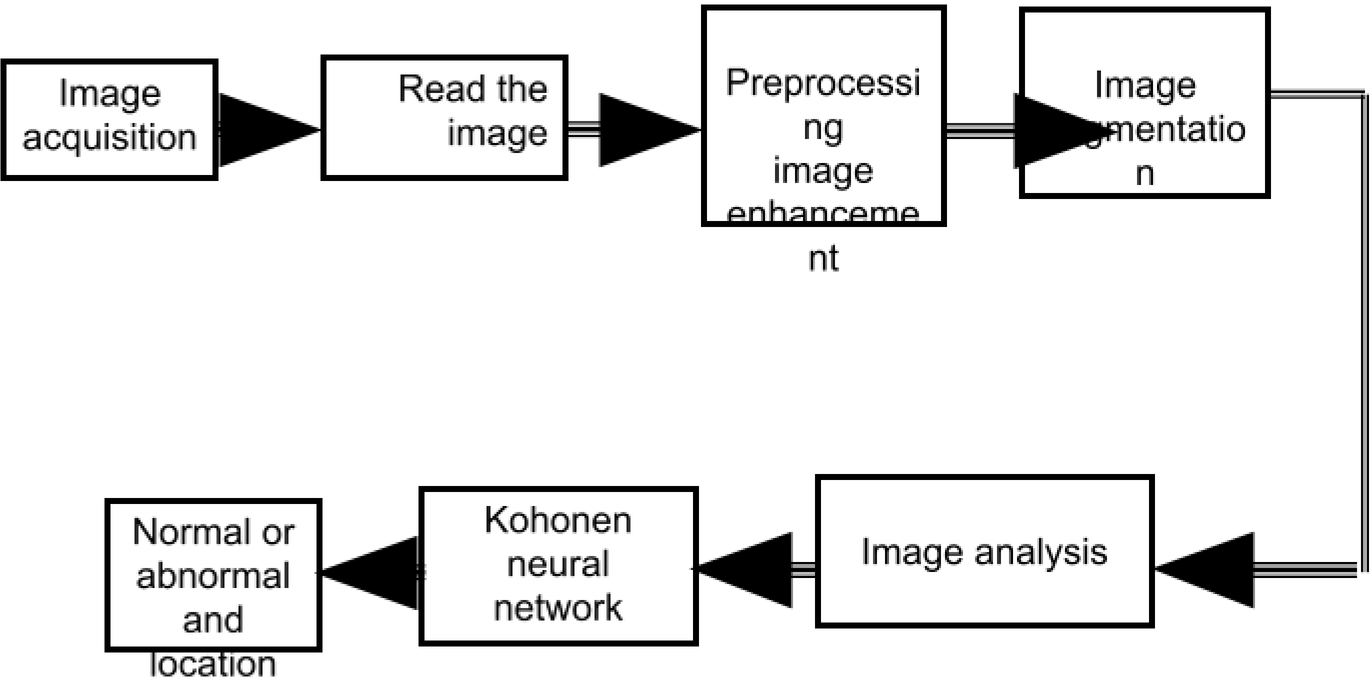

Figure1:The block diagram of the classification system medical image

Image acquisition2 .1.

The first operation is Image acquisition by CT-scan , MRI .

2. 2. Read the image

The basic stage in any image processing system is reading the image file ,where the image data is stored as a file of a specific format .Reading the image file depends on its file format .There are many formats to represent image data .The BMP image format is one of the general proposed formats designated to accommodate images of any size from 1 to 24 bits of color information . The BMP format is the standard way for storing bitmap images in windows applications which used in the proposed system[7].

2.3. Preprocessing

Preprocessing is a stage where the requirements are typically obvious where simple included operators are used to perform initial processing that makes the primary data reduction and analysis task easier ; The operators are used to enhance specific image features [8] .

2.3.1.Image enhancement

1- Image filtering

This stage is the most important one in the system , where the required process is performed on the image such as smoothing noisy images, sharpening fine details of the image , and deblurring the blurred image by selecting an appropriate filter for each operation .This requires two processes [9] : smoothing process and sharpening process.

a. Smoothing process

The smoothing process is applied whenever it is required to reduce the degree of sharpen details in an image, or to reduce the degraded degree in a noise image . This noise may be caused by adding random noisy pixels or by updating the frequency components of the transformed images [10]. This process is achieved by using the following filters:-

1. Mean filter

The Mean filter is a simple sliding –window spatial filter that replaces the center value in the window with the average (mean) of all pixel values in the window [11] **.** The replacement is done with convolution mask such as the following 3*3 mask:

$$\begin{bmatrix} 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \\ 1/9 & 1/9 & 1/9 \end{bmatrix}$$

-a-

Coefficients of this mask sum to one ,so the image brightness will be retained and the coefficients are all positive , so it will tend to blur the image.

2. Median filter

Median filtering doesn't use linear function . A Median filter replaces the pixel in question with the Median of neighborhood. This is useful in removing noise from an image. The Median filter does this by removing large noise spikes from the image [12].

b. **Sharpening process**

This process is the opposite of the smoothing process .It is applied to sharpen the fine details in the requested image ,or deblurring the blurred images, where only the edges are predominant in the image [13].

1.Laplacian filter

The Laplacian masks are rotationally symmetric which means edges at all orientation contribute to the result .The sign of the result from two adjacent pixels locations provides directional information and tell us which side of the edge is brighter .The Laplacian operators different from other operators types in center value of window , it doesn't equal zero but summation of all coefficients of window equal zero . The important Laplacian operators are indicated below [11].

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 4 & -1 \\ 0 & -1 & 0 \end{bmatrix} \quad \begin{bmatrix} 1 & -2 & 1 \\ -2 & 4 & -2 \\ 1 & -2 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix} \quad \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

-a- **-b-** **-c-** **-d-**

2.Robert filter [8]

The Robert filter marks edge points only . It does not return any information about the edge orientation . It is the simplest of the edge detection operators and will work best with binary images . There are two forms of the Robert filter : The first consists of the square root of the sum of the differences of the diagonal neighbors squared as follows.

$$\sqrt{[I(r,c)-I(r-1,c-1)]^2+[I(r,c-1)-I(r-1,c)]^2} \qquad (1)$$

The second form of the Robert filter is the sum of the magnitude of the diagonal neighbors ,as follow:

$$|I(r,c)-I(r-1,c-1)| + |I(r,c-1)-I(r-1,c)| \qquad (2)$$

where

- I(r,c): The pixel in the image .

- r : Index of rows .
- c: Index of columns .

3. Sobel filter

A method to extract all of the edges in an image regardless of its direction. It is implemented as the sum of two directional edge enhancement operations, they are used to highlight the edges and outline the discontinuities in the image. Two types of this filter [14].

$$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \qquad \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

Horizontal mask　　　　Vertical mask

-a-　　　　**-b-**

a-The horizontal mask implements (spatial convolution horizontal mask) dual image pixel point process.

b -The vertical mask (spatial convolution vertical mask) implements pixel group process.

2.4. Image analysis

Image analysis is an important tool for image processing applications .In image applications , image analysis methods may be used to help determining the type of processing required and the specific parameters needed for that processing .It involves the image data to determine exactly the information necessary to help solve a computer imaging problem .This information may include shape parameters to control the textures features which are necessary to diagnose a tumor [15] .

1. Histogram features [16] [17]

The histogram of an image is a plot of gray-level versus the number of pixels at that value .The shape of histogram provides us with information a bout the nature of the image .Histogram is used as a model of the probability distribution of the gray - levels . These statistical features provide us with information about the characteristics of the gray - level distribution for the image . The histogram probability p(g) is defined as :

ρ (g)=N(g)/M (3)

M : is the number of pixels in the image

N(g) :is the number of pixels at gray - level ,as with any probability distribution ,all the values for ρ (g)are less than or equal to 1, and the sum of all the ρ (g) values is equal to 1.

The histogram features are the mean , standard deviation , energy and entropy.

1. The **mean** is the average value .It tells us something about the general brightness of image ,the mean is defined as follows:-

$$\bar{g} = \sum_{g=0}^{L-1} g\rho(g) \quad (4)$$

L: Levels gray scale values =256
g: gray scale values in image
$\rho(g)$: is probability distribution

2. The **standard deviation** tells us something about the contrast .It is also known as the square root of the variance .It is defined as follows:

$$\sigma g = \sqrt{\sum_{g=0}^{L-1} (g - \bar{g})^2 \rho(g)} \quad (5)$$

3. The **energy** measure tells us something about how the gray level is distributed :

$$Energy = \sum_{g=0}^{L-1} [\rho(g)]^2 \quad (6)$$

4. The **entropy** is a measure that tells us how many bits we need to code the image data , it is defined as follows:

$$Entropy = -\sum_{g=0}^{L-1} \rho(g)\log_2[\rho(g)] \quad (7)$$

5. The **skew** measures the asymmetry about the mean in the gray-level distribution. It is defined as :

$$skew = \frac{1}{\sigma_g^3} \sum_{g=0}^{L-1} \left(g - \bar{g}\right)^3 \rho(g) \quad (8)$$

2. Moment invariants [17] [18] [19]

Moments are extracted features that are derived from raw measurements. In practical imagery, images are subject to various geometric distortions or pattern perturbations. It is therefore necessary that features which are invariant to orientations to be used for purposes of recognition or classification. For 2D images, moments have been used to achieve Rotation (R),Scaling (S),and Translation (T) invariants.

The two-dimensional moment for a (***M *N)*** discredited image, ***f(x , y)***.

- **Non- central moments**

The 2-d moment of order (p+q) of digital image f(x,y) is defined as :

$$m_{pq} = \sum_x \sum_y x^p y^q f(x,y) \tag{9}$$

For p,q=0,1,2,.. where the summations are over the values of the spatial coordinates x and y spanning the image .

- **Central moments** are defined as:

$$\mu_{pq} = \sum_x \sum_y (x-\bar{x})^p (y-\bar{y})^q f(x,y) \tag{10}$$

where

$$\bar{x} = m_{10} / m_{00} \tag{11}$$

$$\bar{y} = m_{01} / m_{00} \tag{12}$$

The normalized central moment of order (p+q) is defined as :

$$\eta_{pq} = \mu_{pq} / \mu^{\gamma}{}_{00} \tag{13}$$

for p,q=0,1,2

where

$$\gamma = p+q/2+1 \tag{14}$$

p+q=2,3,..

η_{pq} : is normalized of central moment

3. Artificial neural networks (ANN)

One of the original aims of artificial neural networks (ANN) was to understand and shape the functional characteristics and computational properties of the brain when it performs cognitive processes such as sensorial perception, concept categorization, concept association and learning.

3.1. Kohonen network

Kohonen neural network belongs to the (Winner Takes All) WTA group of networks with the competitive learning algorithm , supervised learning , where the network is trained using a set of input-output pairs. The goal is to ‘teach’ the network to identify the given input with the desired output . The main advantage of this network is its simple structure and simultaneously large abilities. It is similar to the one-layer network but the possibility of application is widened. The network consists of one layer but this layer may be expanded to the two- or more dimensions. The outputs of neurons are WTA type. The idea of contiguity was defined for the Kohonen network , in the one-dimensional network the contiguity is described as the sections on both sides of the selected neuron .The Kohonen network does not require distinct learning process. The weights in the matrix of weights are evaluated in the adaptive way during the network run[20].

The learning vector quantization (LVQ) is a supervised learning extension to the kohonen network method which is used as a pattern recognizer such that each neuron in the output layer represents a class or category (several output may be assigned to each class); The weight vectors are some times referred to as a reference or code book vector. The neuron with closest (Euclidean norm) weight vectors declared to be the winner. Kohonen [1990] is proposed several improvements to LVQ is termed LVQ2, LVQ2.1, LVQ3.All of these devolve around the manner in which the network is trained in particular, training will no longer be exclusively to the winning neuron. The training method rewards a winning neuron if it belongs to the correct category by moving it towards the input vector. Conversely, if the wining neuron does not belong to the correct category, it is punished in that it is forced to move a way from the input. The principal idea behind these improvements is that the two neurons are modified rather than only a winning neuron in LVQ .In other words the winner and runner-up are modified in the same time [21].

4. Winner takes –all learning rule[22]

This learning rule differs from the other rules .This rule is an example of competitive learning ,typically it is used for learning statistical properties of inputs.

$$\Delta w_{mj} = \alpha (x_j - w_{mj}) \quad j=1, 2 \qquad (15)$$

Δw : update weight

X: input vector

W : old weight

Where α >0 is a small learning constant, typically decreasing as learning progresses

$$w_{pi}^{t}x = \max_{i=1,2\ldots p}(w_i^t x) \quad (16)$$

$\max_{i=1,2\ldots p}(w_i^t x)$ =Winner neuron

The learning is based on the premise that one of the neurons in the layer has the maximum response due to input x-this neuron is declared the winner- the individual weight adjustment becomes criterion corresponds to finding the weight vector closest to the input x .

a. **LVQ neural network [12]**

Initialize the weight vectors, wij to random values .It may be beneficial to choose these values when the magnitude is small.

Step 1 Initialize :

Initialize the weight vectors .The weight vectors may be initialized randomly. However, there are some other choices which are going to be discussed shortly . Also initialize the learning rate.

Step 2. for each vector $x^{(p)}$ in the training set there are more steps 2a and 2b .

Step 2a. find the winning neuron k such that :

$$i(x^{(p)}) = k \quad \text{where} \quad \left\|x^{(p)} - w_k\right\| < \left\|x^{(p)} - w_j\right\| \quad j=1,2,\ldots n \quad (17)$$

Step 2b. update the weights w^k as follows:

$$w_k^{new} = \{w_k^{old} + \alpha(x^{(p)} - w_k^{old}) \quad \text{if } T=C^j \quad (18)$$

$$w_k^{new} = w_k^{old} - \alpha(x^{(p)} - w_k^{old}) \quad \text{if } T \neq C^j \quad (19)$$

$x^{(p)}$: All layers

T: The desired class(or category) for training vector

C_j : The actual class of the output neuron

||x- w_j ||: The Euclidean norm between weight vector and input vector.

b.Variation of LVQ[23]

1- LVQ2 can be extended by training both the winning vector and the first runner –up under appropriate conditions . The principal idea is that when the winning neuron does not represent the correct category and the first runner-up does represent the correct category, we may wish to train both , the winner is punished and the runner –up is rewarded LVQ2 imposes the further condition that distance ,dc from the input vector to the winner ,dr the distance between the input vector and the runner-up . The window is defined as follows:

$$dc / dr = 1 - \varepsilon \qquad (20)$$

$$dr / dc = 1 + \varepsilon \qquad (21)$$

dc: The distance from the input vector to the winner.

dr: The distance from the input vector to the runner-up.

ε : constant

When the above conditions are not met ,the training proceeds exactly as before for LVQ.When all of the above conditions are met ,training proceed as follows :

$$w_R^{new} = w_R^{old} + \alpha(x^{(p)} - w_R^{old}) \qquad (22)$$

$$w_c^{new} = w_c^{old} - \alpha(x^{(p)} - w_c^{old}) \qquad (23)$$

w_R ,is the weights of runner-up

w_c ,is the weights of winner

α : learning rate

2. LVQ2.1 [24]

The fine the modification of LVQ , the LVQ2.1 ,here the best two references vectors are trained ,provided that one of them belongs to the correct class and the an other does not best or runner-up , represent the correct class the windowing requirement is as follows:

$$\min[dc_1 / dc_2, dc_2 / dc_1] > 1 - \varepsilon \qquad (24)$$

and

$$\max[dc_1 / dc_2, dc_2 / dc_1] < 1 + \varepsilon \qquad (25)$$

Where dc_1 is the distance from $x^{(p)}$ to wc_1 and dc_2 is the distance from $x^{(p)}$ to wc_2 when the above conditions met ,training proceeds as follows :

$$w_{c1}^{new} = w_{c1}^{old} + \alpha(x^{(p)} - w_{c1}^{old}) \quad (26)$$

$$w_{c2}^{new} = w_{c2}^{old} - \alpha(x^{(p)} - w_{c2}^{old}) \quad (27)$$

dc_1 is the distance from $x^{(p)}$ to w_{c1}
dc_2 is the distance from $x^{(p)}$ to w_{c2}
w_{c1} : is the weight of runner-up

w_{c2} ,is the weight of winner
α : learning rate

3 . LVQ3 [24]

The LVQ3 algorithm a gain varies the windowing condition under which both the winner and the runner – up neurons are trained , where the both neurons belong to different classes ,training proceeds as in LVQ2.1,when both neurons belong to the same class and the windowing criteria in LVQ3 is as follows:

$$\min[dc_1 / dc_2, dc_2 / dc_1] > 1 - \varepsilon / 1 + \varepsilon \quad (28)$$

Training is accomplished as follows:

$$w_c^{new} = w_c^{old} + \beta(x^{(p)} - w_c^{old}) \quad (29)$$

where
$\beta = m1.\alpha(t)$

w_c : is the weight of winner
β : learning rate in the LVQ improvements
0.1< $m1$ <0.5 is typical value of $m1$ is about 0.2.

<u>5. The results</u>

A . Training phase results

This operation starts when the system deals with network structure. The input of the neural network are parameters types that represent the analysis features which enter after normalizing operation of coefficients. The training phase starts randomly to generate weights array whose components have the range of values between (1,-1) and its dimensions are equal to (2*12) is obtained from the analysis . Each column vector be represent by a symbol between (1,2). Then the input of analysis vectors will be compared and matched with weight vectors. The updating these for this weights will be according of LVQ3 algorithm with 30000 the iteration and 0,0001 learning rate and output final weights of each class considers reference file. The figure (2) two images of lung consider two classes for two states (normal, abnormal) consider reference files which used as input for kohonen in training phase.

(1) (2)

Figure (2): Images of lung

(1) Lung abnormal (2) Lung normal

B . Testing phase

In this phase , four image files were taken for each class which are not previously trained for testing operation .To evaluate the systems (70 files of new images) have been used , four files for each class have been compared with the reference file (final weights) previously found to determine the nearest class to the new image file. The figure (3) four new lung images (abnormal) consider new files to compared with the reference files to determine the nearest class to it , this images are used as input for kohonen in testing phase.

Image (3) Image(4)


Image (5) Image (6)

Figure (3): lung images (abnormal)

The Table (1) shows the results of the kohonen network.

	Enhancement+ edge detection					
	Meam &Laplacian	Mean &Sobel	Mean &Robert	Median & Laplacian	Median &Sobel	Median &Robert
Class number	1	2	1	1	1	2
Image number	6	2	4	5	3	2
Analysis coefficients	Image (6) coefficients	Image (2) coefficients	Image (4) coefficients	Image (5) coefficients	Image (3) coefficients	Image (2) coefficients
Non-moment Non-moment Non-moment Central mom Central mom Central mom Central mom Standar devi Skew Energy Entropy Max	0.388238 0.355205 0.168097 0.798690 -0.309390 0.261156 -0.456605 0.798690 0.111775 0.163428 0.107579 -0.417490	0.601328 0.600221 0.279630 0.126940 0.225440 0.855360 -0.470002 0.126940 0.145577 0.127215 0.008383 -0.485883	0.491216 0.490708 0.244795 0.969686 0.126660 -0.150398 -0.378457 0.969686 0.138380 0.156571 0.086493 -0.432753	0.629379 0.616055 0.318210 0.121890 0.131566 0.201198 0.110708 0.121890 0.150923 0.138991 0.007132 -0.532471	0.591166 0.608599 0.305050 0.118451 0.350419 -0.203031 0.130956 0.118451 0.145284 0.138785 0.005048 -0.542867	0.584290 0.599237 0.292975 0.118687 0.466057 -0.169127 -0.202548 0.118687 0.137898 0.135325 0.006632 -0.534031
winner neuron	1	2	1	1	1	2
Distance	1.541097	1.658770	0.354467	2.654876	1.654466	3.654467
Decision	True	true	true	true	True	True

Table(1): The results of the testing phase of system (enhancement &edge detection system)

In this table the results of kohonen test phase .The first column show :

Class number : class(1) means (abnormal lung) and class(2) means (normal lung).
Image number : the number for each test image.

Analysis coefficients: analysis stage of test images (histogram coefficients, moment coefficients).

winner neuron : the results of kohonen network(The neuron with closest (Euclidean norm) weight vectors declared to be the winner).

distance : the distance between winner neuron and reference file .
decision :the match between test images with reference files .

The second row show : smooth and sharp filter which apply on each test image which enter of kohonen.

6. Conclusions

1-The values of normal state images are fixed for each section.

2- The image analysis values are changing, if the image has background unclear.

3-The Kohonen shows success in this system because it can classification of analysis convergence values in different images and give the right decision.

4- The Kohonen network will show large recognition rate if the number of iterations increases.

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