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Designing of Neuro-Fuzzy Based Thermal Imaging System on MATLAB for Detection of Rheumatoid Arthritis

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Abstract— Infrared thermography is one of the options available over the traditional diagnosis methods for measuring and analyzing human body dysfunctions. Thermography gives vital information about temperature variations in different parts of a human body. As infection and inflammation causes temperature changes, thermography exists as a valuable tool for monitoring dysfunctions. Rheumatoid arthritis (RA) is an auto-immune disease that attacks and destroys lubricating elements and healthy tissues of joints of fingers, wrist and feet, causing pain and inflammation over there. Present advanced computer technology can be used to automate the analysis and diagnosis of RA using thermal images of affected area. Thermal Image analysis can be utilized to generate statistics that could be used as input parameters to a Neuro-fuzzy network which can predict the presence of RA. This paper propose to derive important statistical parameters from thermal images and a method to auto-detect RA by using statistical parameters with the help of neuro-fuzzy hybrid network.

Keywords— Rheumatoid arthritis, thermography, infrared, thermal imaging, skewness, kurtosis, Neuro-fuzzy.

INTRODUCTION

Rheumatoid arthritis is an autoimmune disease, in which the immune system starts attacking body's own tissues, causing inflammation. It affects the primary peripheral joints like fingers, wrists, shoulders and feet. This disease results in joint pain, stiffness, swelling of the joints, sometime leads to deformity of joints [2]. Heat is one of the oldest clinical signs of inflammation. So, in case of inflammation the basis of thermography is detection of heat generated by increased tissue blood flow as result of local inflammatory response. [9] Thermography may be used as an valuable tool for diagnosing the rheumatoid arthritis patients [12].

The technique detects infrared radiation intensity which correlates with the temperature distribution of a body region [7]. Infrared thermography provides a digitized output called thermogram. For a normal person, the thermogram shows uniform and symmetric temperature variations. In case of abnormality, abnormal regions show abrupt variations in temperature. The RA region appears as hot spot in the thermogram. [1]

Traditional assessment of the activity of the rheumatoid arthritis includes measurements of the subjective clinical variables, laboratory values and radiographic findings. Considering the change of temperature being basic physical characteristic of the inflammatory process and related reactions, it is justified to consider thermography as a potential, sensitive, noninvasive method for monitoring the severity of the inflammatory disease in both animal models and humans. But there are still two major limitations for infrared thermography used in biological applications. First, the accuracy for low-temperature applications is poor; second, energy distribution is uneven. [3]

Today's improved and advanced software solutions make it possible to incorporate anatomical and physiological information by image processing, which helps to generate information of affected areas. With the advanced computer technology and image processing tools available today, analysis of the images could be done faster with accuracy. Artificial neural networks (ANN) have been used successfully for pattern recognition problems. Once the ANN is properly trained, it can be used to generate consistent output for new sets of inputs reliably and objectively. [4]

METHODOLOGY

Fig. 1 shows the various stages involved in proposed system for detection of Rheumatoid Arthritis which is implemented on MATLAB 2012a.

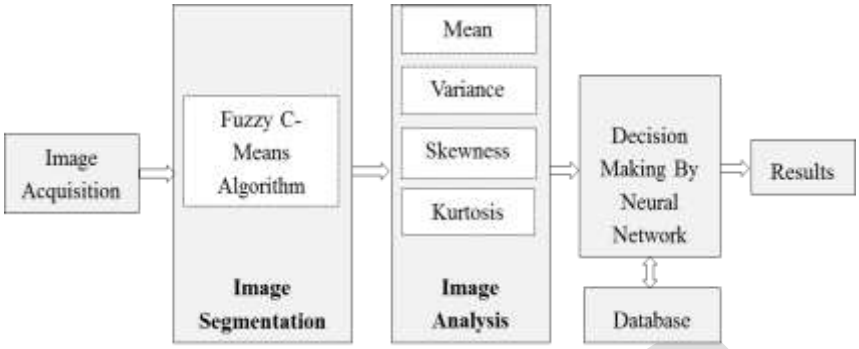

FIG1- STAGES INVOLVED IN DETECTION OF RHEUMATOID ARTHRITIS

1. Image Acquisition

Patients with Rheumatoid Arthritis and the normal persons were included in the study. Thermal image of the affected region of RA patients and normal participants was obtained using FLIR thermal camera. Region to be diagnosed was exposed for 10 minutes in a temperature controlled room set at 20°c. The camera was placed at the distance of 3m to obtain a thermal image in relaxed position. A uniform background was maintained for better segmentation of thermal image.

2. Image Segmentation

The most important step in detection of RA using thermal images is to identify and to segment the region of interest. This can be done by applying segmentation algorithms. Various studies have concluded that Fuzzy C-Means algorithm is better over the other available algorithms. [1, 2] Fuzzy c means (FCM) algorithm uses following steps [1]

For each point x, a coefficient giving the degree of being in the k^{th} cluster $u_k(x)$ is calculated and the sum of all those coefficients is defined to be 1:

$$\forall . x\left(\sum_{k=1}^{num.cluster} u_k(x) = 1\right) \quad \text{..... (1)}$$

IN FCM, the centroid of a cluster is the mean of all points, weighted by their degree of belonging to the cluster:

$$\text{Center k} = \frac{\sum_x u_k(x)^m x}{\sum_x u_k(x)^m} \quad \text{..... (2)}$$

The degree of belonging is related to the inverse of the distance to the cluster center

$$u(k)_x = \frac{1}{d(center_k, x)'} \quad \text{..... (3)}$$

Then the coefficients are normalized and fuzzyfied with a real parameter $m > 1$ so that their sum is 1. So

$$u(k)_x = \frac{1}{\sum_j \left(\frac{d(center_k x)}{d(center_j x)}\right)^{\frac{2}{m-1}}} \quad \text{..... (4)}$$

The steps involved in fuzzy c means algorithms are as follows:

- The number of clusters are chosen.
- Random co-efficient are assigned to each point in the cluster
- Exponent weight m is chosen.
- The membership function u_k is initialized.
- The centroid for each cluster is found by using the equation (2).
- The coefficients for each points in the clusters are computed using the equation (3) and (4).

3. Image Analysis

Statistical parameters can be used as pre-processing model for various digital image processing technique to improve the effectiveness of complex image processing technique in the next levels [11]. This section aims to derive various statistical parameters from segmented image that could be used as input to a neuro-fuzzy network for predicting the presence of RA. The image intensity directly

depends on thermal energy distribution of an object. A histogram expresses the delivery intensity and explains image combination. A histogram provides statistical information about the texture of the image. [10]

If P_j is the probability density of the j^{th} bin in the histogram and N is the total number of bins then these parameters can be defined as follows:

$$\text{Mean } \mu = \frac{1}{N}\sum_{j=1}^{N} P_j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\text{Variance } \sigma^2 = \frac{1}{N-1}\sum_{j=1}^{N} (P_j-\mu)^2 \quad \ldots\ldots\ldots\ldots (6)$$

$$\text{Skewness} = \frac{1}{N}\sum_{j=1}^{N} \left(\frac{P_j-\mu}{\sigma}\right)^3 \quad \ldots\ldots\ldots\ldots\ldots (7)$$

$$\text{Kurtosis} = \frac{1}{N}\sum_{j=1}^{N} \left(\frac{P_j-\mu}{\sigma}\right)^4 \quad \ldots\ldots\ldots\ldots\ldots (8)$$

The acquired thermal image as well as segmented image have variable pixel values over a long range, therefore extraction of useful information from both the images is quite complex to detect the presence of disease. For better feature extraction original image is first inverted and then added to segmented image. Statistical parameters are calculated in MATLAB by using the standard equation as expressed in equation (5), (6), (7) and (8) for the overlapped image.

4. Decision Making by Neural Network

Back Propagation neural network is applied extensively in pattern recognition problems. In this paper a feed forward network with an input layer, an output layer and at one hidden layer is used. Neural Fitting Tool (nftool) of Neural Network toolbox is used in MATLAB 2012a to create a neural network. The number of neurons in input layer and hidden layer is set to 4 while the number of neuron in output layer is set to 1. The four parameters Mean, Variance, Skewness and Kurtosis act as input to the Neural Network. The Network is trained for 20 input samples with corresponding target outputs by using Bayesian Regularization algorithm. A MATLAB function is generated at the end of training which returns the output of neural network to main program. Returned value is compared to a threshold value and according to predefined rules results are displayed on MATLAB GUI.

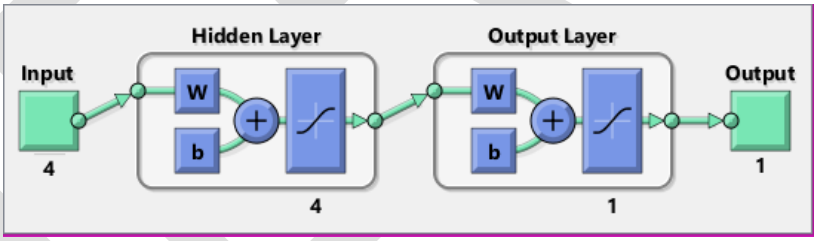

Fig. 2 Neural Network Architecture in MATLAB 2012a

RESULTS AND DISCUSSIONS

The calculated mean, variance, skewness and kurtosis values of pixels in thermal image of four RA patients and four normal participants for palm is listed in the Table-I.

Table I: Derived Parameters Value For Palm of Normal persons

Sample No.	Mean	Variance	Skewness	Kurtosis
Sample 1	242.55	56.462	-0.069	0.136
Sample 2	243.21	53.704	-0.063	0.123
Sample 3	244.63	55.888	-0.054	0.126
Sample 4	243.58	63.126	-0.046	0.142

Table II: Derived Parameters Value For Palm Of Persons With Rheumatoid Arthritis.

Sample No.	**Mean**	**Variance**	**Skewness**	**Kurtosis**
Sample 1	240.21	53.704	-0.063	0.233
Sample 2	235.64	56.897	-0.055	0.112
Sample 3	241.16	56.376	-0.052	0.195
Sample 4	238.40	55.550	-0.060	0.201

Fig 3 shows the GUI created in Matlab 2012a. The MATLAB program was capable of detecting disease correctly with the hit rate of approximately 60% for total 20 thermal images of normal and abnormal cases.

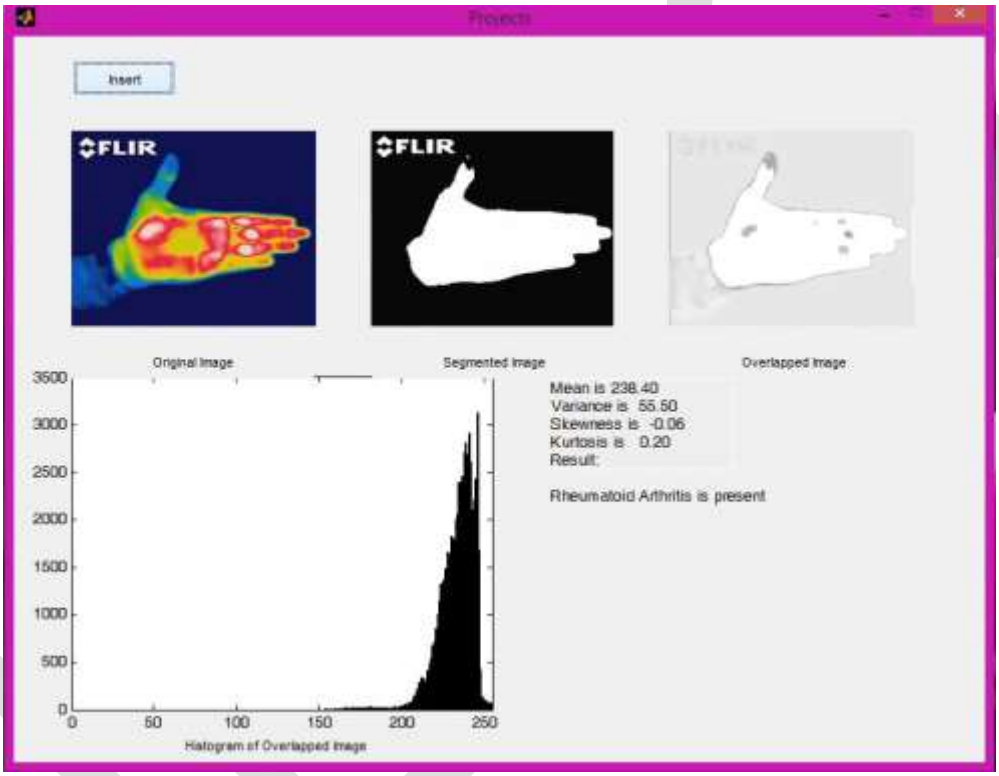

FIG3- MATLAB GUI FOR DETECTION OF RHEUMATOID ARTHRITIS USING THERMAL IMAGES

CONCLUSION

Thermography is a diagnostic method useful as a complementary method to other medical tests. It is concluded that some standards need to be defined for improving the diagnostic strength of thermography. So, further intensive researches in thermography application with creating specific data bases that can be used as algorithms are needed.

Neural Network provides intelligence to the system and makes it capable of auto detecting the RA disease. Multiple configurations have been checked by changing the number of neurons but a 4-4-1 network is found most suitable.

In conclusion, thermal imaging with neural network provides an alternative method to existing technology for auto-detection of the Rheumatoid Arthritis. This technique can be further expanded for detection of some other diseases.

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