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IKRAI: Intelligent Knee Rheumatoid Arthritis Identification

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Abstract—Rheumatoid joint inflammation is characterized as a perpetual incendiary issue which influences the joints by hurting body tissues Therefore, there is an urgent need for an effective intelligent identification system of knee Rheumatoid arthritis especially in its early stages. This paper is to develop a new intelligent system for the identification of Rheumatoid arthritis of the knee utilizing image processing techniques and neural classifier. The system involves two principle stages. The first one is the image processing stage in which the images are processed using some techniques such as RGB to grayscale conversion, rescaling, median filtering, background extracting, images subtracting, segmentation using canny edge detection, and features extraction using pattern averaging. The extracted features are used then as inputs for the neural network which classifies the X-ray knee images as normal or abnormal (arthritic) based on a backpropagation learning algorithm which involves training of the network on 400 X-ray normal and abnormal knee images. The system was tested on 400 x-ray images and the network shows good performance during that phase, resulting in a good identification rate 95.5 %.

Index Terms—Rheumatoid arthritis, intelligent identification, neural classifier, segmentation, backpropoagation.

I. Introduction

Rheumatoid arthritis (RA) or joint inflammation can be characterized as a complex incendiary auto-immune infection which is connected with impressive disability, horribleness, and mortality [1]. Early distinguishing proof of patients with forceful dangerous infection is vital, for prognostic furthermore remedial reasons. An alternate definition for the Rheumatoid joint pain is a ceaseless incendiary issue which may influence the joints of the fingers, knee and hands and this leads to swelling, firmness and agony.

The early Rheumatoid joint inflammation tends to influence the littler joints first, in especially the joints that connect fingers to hands and toes to feet. The extent that the sickness creates, indications frequently spread to the wrists, knees, lower legs, and elbows. The signs and side effects of Rheumatoid joint pain may fluctuate in seriousness and advancement and may additionally travel every which way. Over the long run, rheumatoid joint inflammation may cause joints to distort and move out of its place [2]

The narrowed distance between the femoral and tibial bones, cartilage loss, and bone spurs are the basic signs of that disease [3]. In our identification system, we focus on extracting these features using some image processing techniques, in order then to be fed to a backpropagation neural network which has the ability of classification images into normal or abnormal after convergence using a large number of images obtained from our created database which contains normal and arthritic knee X-ray images.

The need of such a system is due to the lack of intelligent systems of classifying the x-ray knee images. Most of the previous researches focused on the image analysis of x-ray knee rather than identifying it using intelligent systems. Thus, such an intelligent system is in urgent need due to its simplicity and effectiveness. This paper highlights the use of different and more accurate methods results in less diagnosing error and higher classification rate of the knee Rheumatoid arthritis.

The paper is structured as follows: section one is an introduction about the paper, aims and structure. The section two is a literature review about the proposed topic, while section three discusses the images database and number of images used for training and testing the network. Section four describes the proposed method through its two phases: image processing and classification. The last section is a conclusion about the proposed work.

II. Litterature Review

At the present, a lot of examination has been carried out in image processing for therapeutic field according to the determinations of conclusion; however the quantity of intelligent and positive x-ray knee images classifying developed systems that stimulates the human visual inspection in order to make the right decision on which the knee is normal or abnormal (arthritic) is extremely low and restricted. This prompts error and the used techniques are not solid for proceeding. Different divisions, and grouping procedures taking into account discrete cosine transform (DCT), NCuts Algorithm, SOFES Algorithm and segmentation have been utilized to perform and help in diagnosing the Rheumatoid arthritis [4]. The drawback of these systems is that they are still insufficient since they can't manage the images scans legitimately and they can't provide an accurate fitting diagnosis.

The authors in [5] proposed an intelligent assistive system for the diagnosis of Rheumatoid arthritis using histogram smoothing and feature extraction of bone images. The authors aimed to use a series of image processing techniques on bone images, in order to accurately detect the occurrence of rheumatoid arthritis (RA). In their system, the images undergo different image processing techniques such as histogram smoothing, filtering, morphological operations, and also segmentation as a method to extract the patterns of interest of the processed image. A Gray Level Co-occurrence Matrix is also used to extract some features form the region of interest such as mean, energy, correlation etc… These features are then fed into a neural network that classifies them into inflamed and non-inflamed images. The weakness of such system is that there may not be a difference in the texture features values of the normal and abnormal images. Therefore, in our proposed system, we attempt to stimulate the human visual inspection of classifying an x-ray knee image by extracting the right features that distinguish normal and arthritic x-ray knee image which are the distance between the femoral and tibial bones, and the bone spurs that may appear if the knee is affected.

III. System Database

In general, the RA is screened by using conventional x-ray or MRI. In this paper we used the x-ray images taken by conventional X-ray diagnostic machines. The produced images of this machine are examined by a doctor or physician who makes the final decision based on some visible features seen in the image. However, our new approach to RA intelligent identification is based on artificial intelligence using image processing and intelligent classifier which models the human visual recognition who is normally able to identify the Rheumatoid arthritis according to some morphological features such as the narrowed distance between bones and some bone spurs. The normal and abnormal images were collected from different websites and centers for RA of knee diagnosis, and then these images were rotated incrementally by 15 degree to finally get 6 images for each one; including the original image. The total number of images is 800 images. Among them, 350 are normal and 450 abnormal images (arthritic knees). Table 4 shows the number of normal and abnormal images.

Table 1. Number of database images

	Number of normal images	Number of abnormal images	Total Number of Images
	350	450	800
Training set	175	225	400
Testing set	175	225	400

IV. The Proposed Identification System

The proposed identification system comprises of two primary stages which are the image processing stage and the classification stage. In the first stage the images are prepared utilizing numerous methods, for example, change to grayscale, rescaling, filtering using median filter, segmentation using canny edge detection, and feature extraction using pattern averaging. These procedures are utilized to improve the quality of images and concentrate the imperative peculiarities, for example, separate between the femoral and tibial bones and bone goads or spurs. Toward the end of this stage, the images are prepared to be sustained to the following stage which is the neural system in which they are classified as normal or abnormal (arthritic). Fig.2 demonstrates the flowchart of our new algorithm for the identification of Rheumatoid arthritis. Fig.3 outlines a typical knee x-ray image that experiences the proposed image processing techniques.

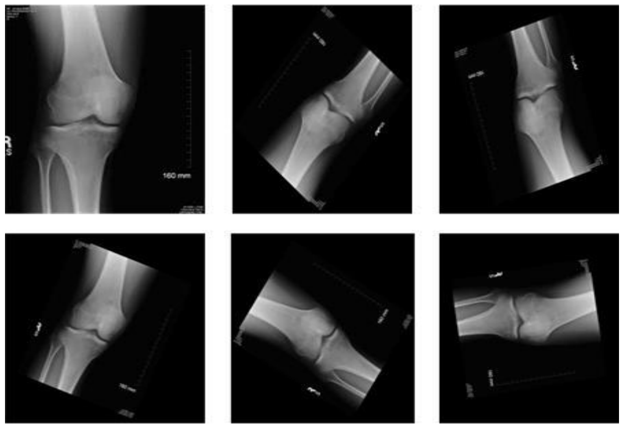

Fig.1. Normal knee image rotated to 15 degree incrementally to produce 6 images including the original one.

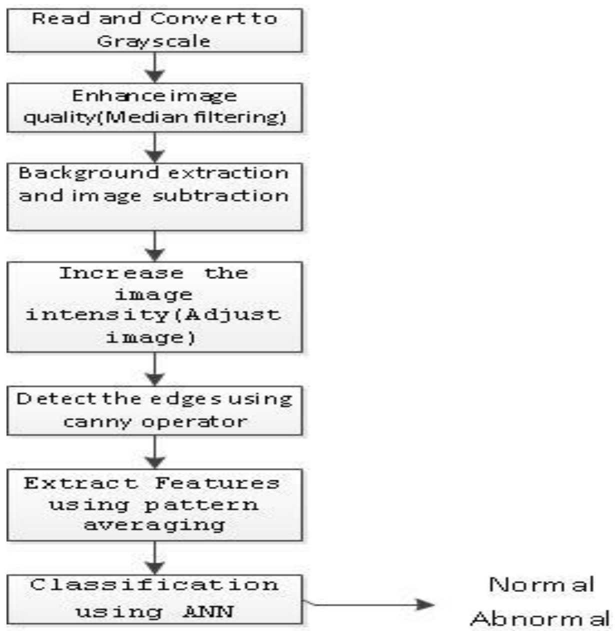

Fig.2. Flowchart of the proposed system

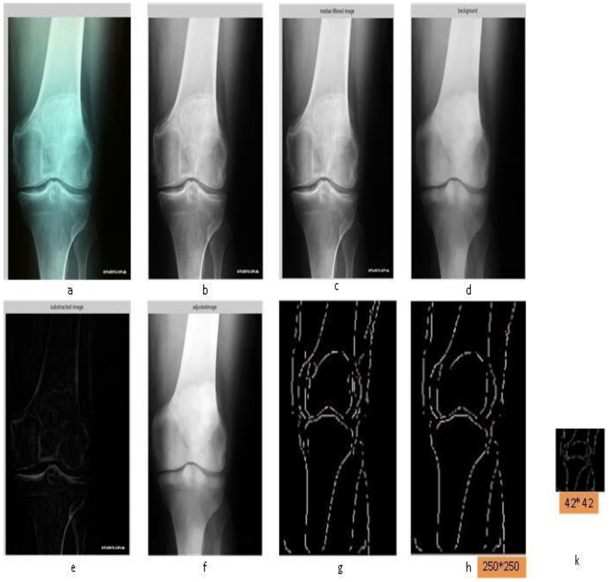

Fig.3. The proposed system algorithm. (a) Original RGB normal knee image, (b) Grayscale image, (c) Filtered image using median filter, (d) Background image, (e) Subtracted image, (f) Adjusted background image, (g) Segmented image, (h) Cleaned image, (k) Extracted features using pattern averaging.

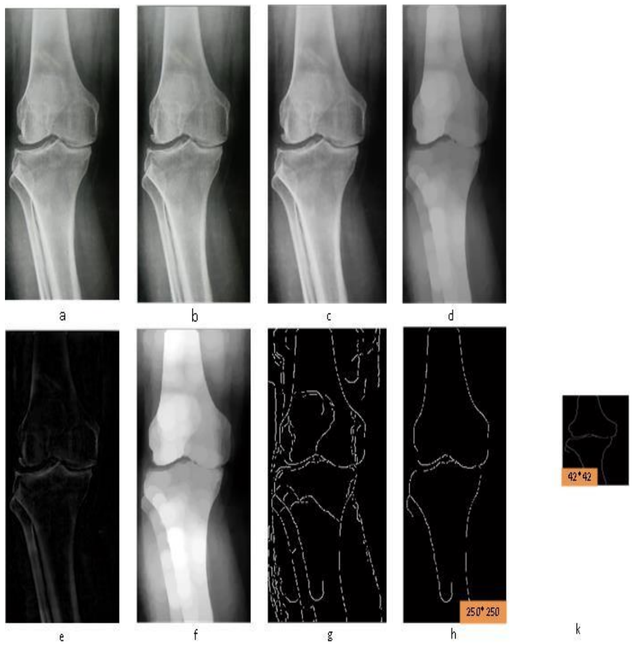

Fig.4. The proposed algorithm for an abnormal knee image. (a) Original RGB abnormal knee image, (b) Grayscale image, (c) Filtered image using median filter, (d) Background image, (e) Subtracted image, (f) Adjusted background image, (g) Segmented image, (h) Cleaned image, (k) Extracted features using pattern averaging.

A. *Image Processing Phase*

During this phase, different image processing techniques are used in order to process the images to be ready for the next phase; the classification phase. The used techniques are as follows:

a) Grayscale conversion: the images are converted from RGB to grayscale using luminosity method [6].

b) Median filtering: The most common types of filters for smoothing purposes are the linear filters such as the median filter which is used in our proposed system. This filter is used to reduce impulsive noise or the salt-and pepper in an image with preserving the useful features and image edges. It is a linear process in which the output of the being processed pixel is found by calculating the median of a window of pixels that surrounds that studied pixel [6, 7].

Fig.5. Median filtering. (a) original image, (b) medial filtered image

c) Background extraction: The extraction of background is achieved using a morphological technique called image opening. This technique can be defined as erosion followed by dilation using the same structure element for the two morphological operations. In this technique, the objects that cannot completely contain the structuring element are removed in order then for the background to be extracted [7, 8].

Fig.6. Background extraction. (a) Original filtered image, (b) extracted background

d) Image subtraction: the original image is subtracted from the background image in order to produce a new image with better quality. This operation is performed using a pixel subtraction operator that takes two images as input and produces as one image as output. The pixel values of the output are simply the pixel values of the first image minus the pixel values of the second image [8].

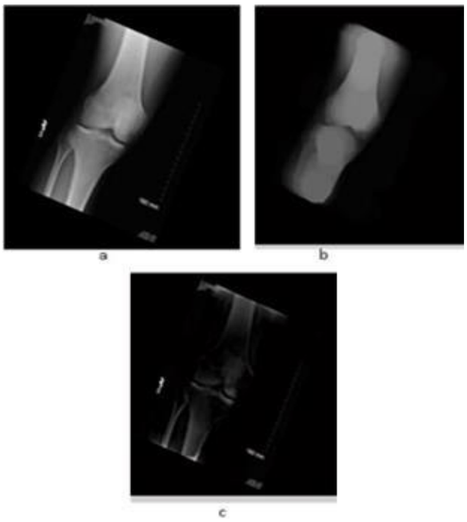

Fig.7. Image subtraction. (a) Original image, (b) background image, (c) Result image

$$R(i,j) = O(i,j) - B(i,j) \quad (1)$$

Where O and B represent the original and background image respectively. O(i,j) and B(i,j) represent the elements values of the original and background images matrices in which the number of elements of both matrices must be equal.

e) Image adjustment: For the purpose of increasing the image intensity and enhance its quality, the images undergo intensity adjustment. This image processing technique aims to enhance the contrast of the image by increasing the intensity of its pixels. During this operation, the intensity value of each pixel in the input image is transformed using a transfer function to form a contrast-adjusted image. Gamma contrast adjustment is the most common used transfer function [7, 8].

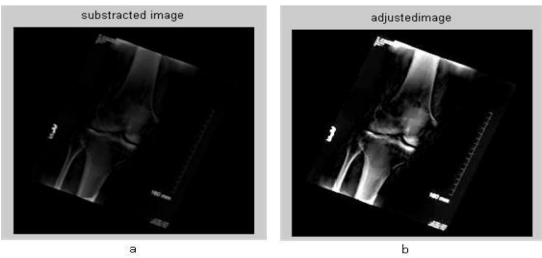

Fig.8. Image adjustment. (a) Subtracted image, (b) adjusted image of a.

f) Segmentation based canny operator: the segmentation is the grouping of interesting regions of the image into foreground regions of interest and background regions to be ignored using some techniques [9]. In this proposed system, we detect edges using canny operators. This technique is the most common used method for detecting edges and segmenting the image. The Canny edge detector is considered as one of the best currently used edge detectors since it provides good noise immunity and detects the true edges or intensity discontinuities while preserving a minimum error [10, 11].

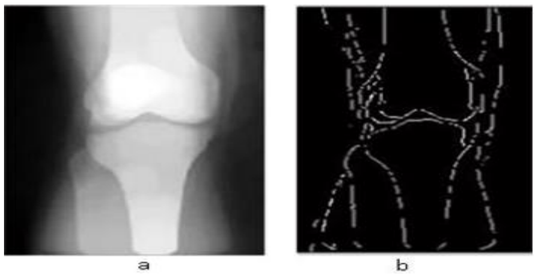

Fig.9. Canny edge detection. (a) Background image, (b) segmented image using canny operators

g) Clean the image: After segmenting, the images are cleaned in which some unuseful components are removed. This is achieved using a matlab function called "bwareaopen". This function is an image processing technique used in order to remove or clean the image from the unneeded components. A certain value is set and all connected components that have pixel values higher than that value are removed [7,8].

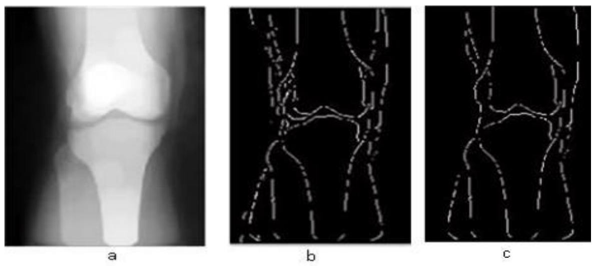

Fig.10. Clean the segmented image. (a) Original image, (b) segmented image, (b) cleaned image

h) Feature extraction using pattern averaging: To reduce the size of images while keeping the useful and needed features extracted by the previously used methods, we used pattern averaging. This technique is defined as the averaging of the defined segments of the image by selecting a window of 6*6 segments that are averaged. Therefore, each studied pixel is then the average of the 36 neighbor's pixels in the selected window [12, 13]. Thus, we come up with a rescaled image with the same features and properties of the original one for the purposes of easy computing. Below in Fig.6, some of processed rescaled images are shown.

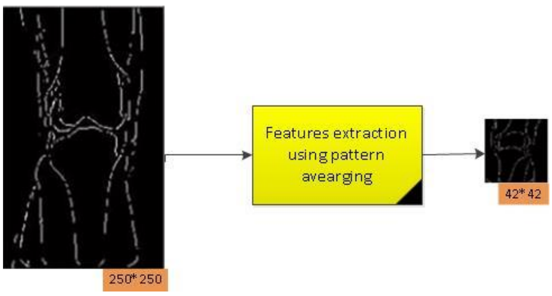

Fig.11. Feature extraction

B. Classification Phase

1. System Training

During this phase, the x-ray images of knee are classified into normal or abnormal using a supervised neural network. We used a backpropagation neural network due to its simplicity and the sufficient number of images [14]. We used 400 images, 150 are normal and 250 are abnormal (arthritic knees). The system was trained on 400 images; 175 for normal knees and 225 for abnormal knee images. The input layer of the network consists of 1764 neurons since each image is rescaled to 42*42 bitmap using pattern averaging. The hidden layer consists of 5 neurons, while the output layer has 2 neurons since we have only 2 output classes: normal and abnormal. Figure 4 shows the neural network topology of our proposed identification system. Table 1 represents the input parameters setting of the system

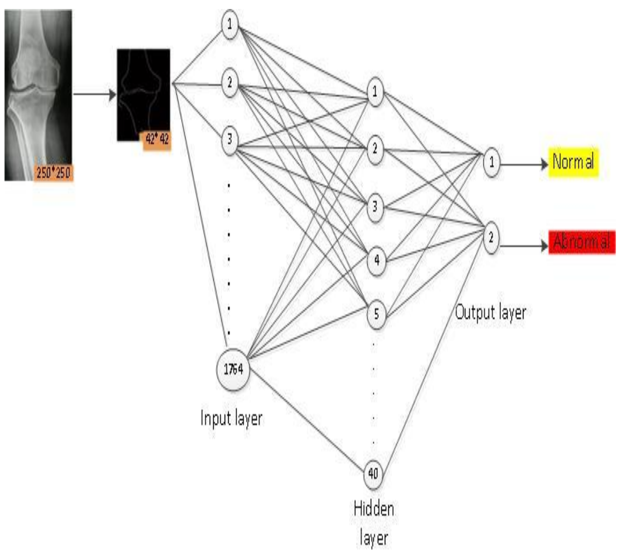

Fig.12. ANN topology

Table 1 represents the input parameters setting of the system. Table 2 shows all the parameters used when training the network. The network ran for 5000 iterations with a learning rate of 0.001, a momentum rate of 0.4 and a minimum error of 0.001 since it is a medical application.

Table 2. ANN Parameters Setting

Parameters	Value
Number of neurons in input layer	1764
Number of neurons in output layer	2
Number of neurons in hidden layer	40
Iterations number	5000
Learning rate	0.001
Momentum rate	0.4
Error	0.001
Activation Function	Sigmoid

The following is the training results of the two sets (learning curve).

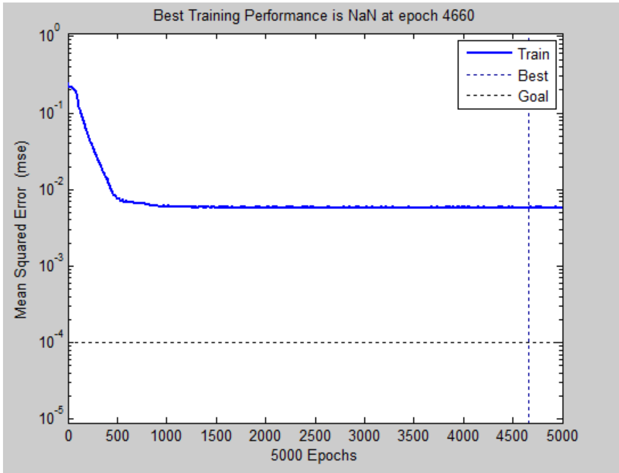

Fig.13. Learning curve of the training phase

This figure below represents the regression plot of the desired output (dotted line) and the actual output. As the actual output is far from the target as the error is increased. In this figure, it is remarked that the target and the actual output are almost overlapped which means that the error is minimized and the network well trained (training ratio = 100%).

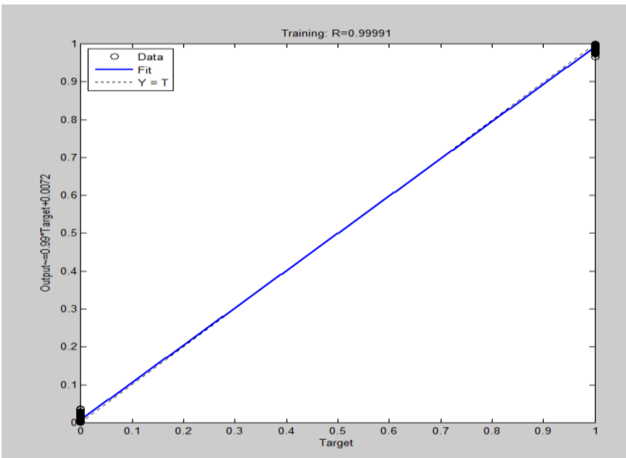

Fig.14. Regression plot of the proposed system

2. Experimental results

This paper introduces an intelligent identification system established image processing and neural classification. The images are processed in order to extract the patterns of interests using image processing techniques. The images then bear pattern averaging in order to rescale them while retaining the extracted useful features. Fig. 9 shows the process of our system which comprises of two phases in including feature extraction.

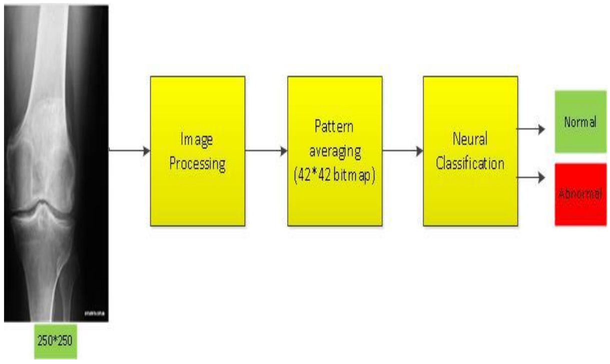

Fig.15. The phases of the proposed identification system

This identification system was tested using MATLAB software and tools. It was tested using 400 images; 175 for normal and 225 for abnormal images. Each image passes through the process shown in Fig. 15 to be processed, segmented, rescaled using pattern averaging, and then classified using the neural network classifier. The result of both testing and training phases is included in the following table.

Table 3 represents the recognition or identification rate obtained in both training and testing phases. It also shows the number of images used in each set, as well as the overall identification rate obtained which is 95.5%.

Table 3. The identification rate

Knee images type	Image sets	Number of images	Identification rate
Normal	Training set	175	100%
	Testing set	175	95%
Abnormal	Training set	225	100%
	Testing set	225	96%
Total identification	Both sets	800	95.5%

Table 4. Different identification rate for different input parameters

Learning rate	Momentum rate	Nb. Of hidden neurons	Epochs	Identification rate
0.04	0.3	10	10000	81 %
0.05	0.4	15	10000	83 %
0.02	0.66	25	5000	89 %
0.007	0.5	40	5000	95.5 %

Table 4 shows the identification rate obtained for different input parameters values. It is remarkable that the increase of the number of hidden neurons results in a better and higher identification rate.

V. Conclusion

In this paper, a new intelligent approach for the identification of Rheumatoid arthritis is proposed. This novel approach is based on image processing and artificial neural network. The x-ray knee images are processed to extract the patterns of interests. The processed images are then rescaled using pattern averaging that assures the reduction of image size while keeps the useful features. The features are then used as inputs to the neural network that has the capability of classifying them into normal and abnormal through its learning phase, in which it was trained using 400 normal and abnormal x-ray knee images. The robustness of the proposed system is that it stimulates the human visual inspection that usually identifies the Rheumatoid arthritis according to some signs or features such as distance between the tibial and femoral bones, and bone spurs. Hence, pattern averaging technique allows us to preserve these features though the size of images was reduced.

A database was created by getting some X-ray normal and abnormal images form Rheumatoid arthritis diagnosing centers. The images were then rotated in order to get large number of images for training and testing purposes. Moreover, rotating images aims to create a robust system that has the capability of capturing classification regardless of image orientation. After convergence, the network was tested and identification rate was satisfactory which proves that such system can be developed as full computerized machine or embedded in a biomedical device.

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