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Classification of Kidney Images using Particle Swarm Optimization Algorithm and Artificial Neural Networks

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Abstract: *Ultrasound (US) imaging is used to provide the structural abnormalities like stones, infections and cysts for kidney diagnosis and also able to produce information about kidney functions. The main aim of this work is classifying the kidney images by using US according to relevant features selection. In this work, images of kidney are classified as abnormal images by pre-processing (i.e. grey-scale conversion), generate region-of-interest, extracting the features as multi-scale wavelet-based Gabor method, Particle Swarm algorithm (PSO) for optimization and Artificial Neural Networks (ANN). The PSO-ANN method is simulated on the platform of MATLAB and these results are evaluated and contrasted. The results obtained through this method are better in terms of accuracy, sensitivity and specificity.*

Index Terms: *Artificial Neural Networks, Gabor feature extraction, Kidney diagnosis, Particle Swarm Optimization, Ultrasound images.*

I. INTRODUCTION

The major and fundamental problem in many medical image analysis tasks is creating the correspondences between images [1]. The diagnosis of diseases can be affected by any error in medical imaging, hence the difficult task in medical field is to find the accurate identification of images for classification. The medical examinations and numerous data are collected from clinical trials for ensuring the statistical significance of studies. The laboratory results and clinical analyses are collected from datasets is useful for quality control, investigation of medical research, studies on epidemiology and so on [2], [3].

Several imaging implications and technologies are covered by vast medical imaging, such as X-ray-based methods in optical imaging. Sonography is also called US is used for producing pictures inside the body by exploring the parts to high frequencies. The diagnosis and therapeutic procedures are made by invasive imaging technologies which are offered by US. The scanning of US is used to scan the organs of the body like gallbladder, bladder, liver, ovaries, spleen, kidneys, pancreas, uterus and fetus in pregnant patients [4],[5]. The complex geometric problems are solved by some effective algorithms like three-dimensional (3D) modeling, sharp extraction and classification method in medical image processing.

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The typical geometric problems can be identified by contour data points which connect a proper surface [6], [7]. Segmenting the medical images is considered as a basic of analysing and understanding the images in medical field [8]. In recent years, many software tools are available for segmentation in both open-source and commercial. But, the open-source software cannot support the parallel image processing [9]. Therefore, more number of existing methods used either combing the low-level features or discarding the set of features for classification [10], [11]. In this work, the kidney images are trained and tested for classifying the images as normal or abnormal kidney images. The images are segmented and the features are extracted by Gabor feature extraction method and these extracted features are selected by using PSO-ANN method. The experiments were conducted on MATLAB and the performance of the method was evaluated by metrics such as Accuracy (Acc), Sensitivity (Sen) and Specificity (Spec).

II. PROBLEM DEFINITION

The automated system is developed for diagnosis of the kidney diseases by using ultrasonic systems in recent years. During imaging, the system allows the extraction of vast data and good quality of information to detect the diseases. The evaluation of global conditions can be made by the process of feature extraction, analysis of images and classify the images by pattern recognition techniques. But no technique had yet improved the accuracy of the system or proved to be best in accuracy for classifying the kidney diseases. Therefore, the classification accuracy will be improved with the help of improving the existing pre-processing as well as classification model. This above mentioned limitations and the lack of solutions motivated this research work.

III. PROPOSED METHODOLOGY

In this work, the accuracy of the classification results can be improved by implementing the computer-aided system for classifying the normal and abnormal US kidney images according to extraction of features and classification methods. The proposed method involves extracting the features based on multi-scale wavelet and classifying the images with the help of ANN in which the parameters are optimally chosen through PSO. In first step, the multi-scale wavelet features are extracted from ROI of each image. The ANN is used for classification of kidney images through extracted features and provides the better classification by combined with PSO algorithm.

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Figure 1 details the basic structure of feed based abnormality classification method.

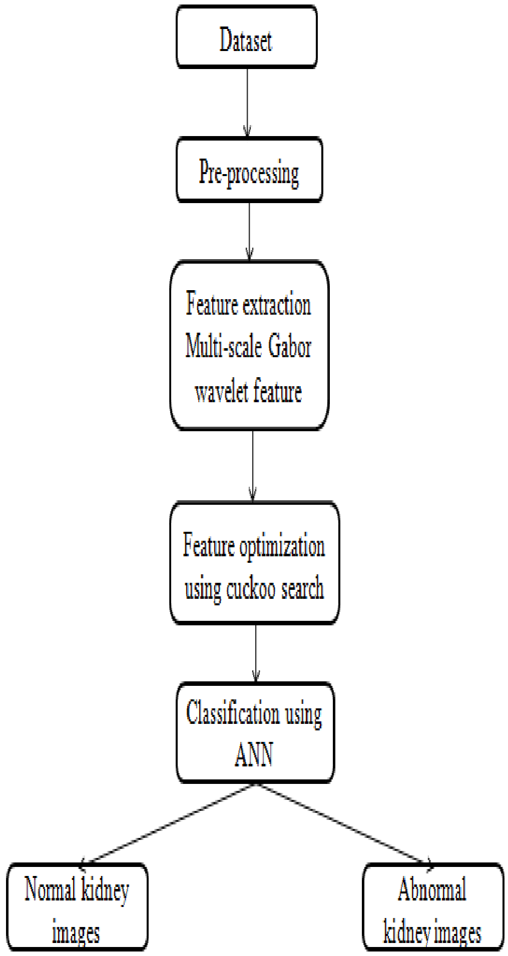

Figure 1: Basic structure of proposed methodology

A. *Preprocessing*

The PSO-ANN method is preprocessing the kidney image which is considered as the first step. The unwanted noise components in the images are removed by using pre-processing. The PSO-ANN method uses the colour-to-gray conversion for reducing the complexity. At last, the interference of irrelevant regions is reduced by using ROI generation.

B. *Extraction*

The selected features represent the uniqueness of the images for defining a class. In this work, the Gabor features are extracted to classify the kidney images. The extraction of features is done from many frequencies or scales that are aligned at various angles with the help of Gabor filtering. The wavelet decomposed images are used for evaluating the Gabor features. The Eq. (1) describes the Gabor filter as:

$$g(z,w,\gamma,\omega) = \frac{1}{2\prod\sigma_z\sigma_w} e^{\frac{1}{2}\left(\frac{z_1^2}{\sigma_z^2}+\frac{w_1^2}{\sigma_w^2}\right)} \quad (1)$$

where σ_z and σ_w are the standard deviations in z, w directions; $\gamma = 1/central\ frequency$ represents the wavelength and ω represents the orientation angle. The major details of the kidney's shape and patterns can be predicted by the frequency and orientation. Here, the six different orientations and four different wavelengths are used for extracting the features. The Eq. (2) and (3) can be summarized the parameters z_1 and w_1,

$$z_1 = z\cos\omega + w\sin\omega \quad (2)$$

$$w_1 = -z\cos\omega + w\sin\omega \quad (3)$$

From the Gabor filter, $g(z,w,\gamma,\omega)$, the Gabor features can be extracted as

$$F(g) = F(z,w) * g(z,w,\gamma,\omega) \quad (4)$$

The six orientations and four different central frequencies are evaluated by the Gabor features and produce 24 features for every decomposition of kidney images. According to the extracted features, the classification of normal or abnormal images is a tedious process. Therefore, reducing the features must be carried out for better classification accuracy. In this proposed work, Probabilistic Principal Component Analysis (PPCA) is used for selecting the best features.

C. *Feature Selection*

The most challenging task is selecting the correct number of features for better classification. The problem of over-extraction and under-extraction can be formed by an incorrect choice. PPCA is an effective tool for reducing the data set dimension and also allows reconstructing the optimal shape. While most of the variations are retrained, the dataset contains vast number of interrelated variables. For reducing the feature dimension, projection vectors are used which contribute to highest covariance. The computation of low-dimensional representation with a probability distribution of high-level dimension data by PPCA .is done. In this work, K-eigen vectors are selected from the feature input by PPCA for choosing the best features from the whole extraction of features.

D. *Feature Optimization*

The PSO algorithm is considered as an adaptive method to solve the optimization problem. In evolutionary algorithm, the particles population can be used for searches in which each particle belongs to individual. Initially, a particles of swarm is randomly generated, a possible solutions point represents each particle's position in the problem space. X_i is a position vector and V_i is a velocity vector of each particle should be updated by moving through problem space. Kennedy proposed the formula of updating position vector X_i:

$$x_{k+1}^i = x_k^i + v_{k+1}^i \quad (5)$$

and the formula of updating velocity vector V_i:

$$v_{k+1}^i = w_k v_k^i + c_1 r_1 (p_k^i - x_k^i) + c_2 r_2 (p_k^g - x_k^i) \quad (6)$$

where c_1, c_2 are positive constant and r_1, r_2 are uniformly distributed random number in [0,1]. The velocity vector V_i is range of $[-V_{max}, V_{max}]$.

A function F_i is measured by position vector X_i for calculating particle's quality at each iteration step. The vector P_g describes the best position in the population and P_i presents ever the best position of each particle. In this work, PSO computes the minimum values of Mean Square Error as fitness values.

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E. Classification

The finding of patterns and the computation method for data is referred to as Classification, which is used to train the tumor images with ANN. The simple components are interconnected with each-other in Neural Network which consists of neurons and having the similar property of biological neurons. The output obtained from neurons as a function of $F(Y)$ input vector $(X1, X2 \dots\dots Xn)$.

$$Y_i = \sum_{j=1}^{k} W_{ij}\ X_i \qquad (7)$$

The Weighted sum (Wij) and corresponding neurons are contained in a multilayer perception network. The information can flow in a direction along all the connecting paths in ANN method. The hidden layer without feedback is used to pass information from input to output. According to the gradient descent, back propagation is used for calculating the derivative performance with respect to each bias variable and weight is adjusted.

IV. RESULTS AND DISCUSSION

The PSO-ANN algorithm is evaluated with the help of MATLAB software using a system with 4 GB RAM and 2.10 GHz Intel i-3 processor. In this section, the experiments were conducted for analysis of the PSO-ANN with other existing works such as ANN, GA-ANN, KNN and Bayes algorithm. According to various factors, the prediction efficiency is measured.

A. Database Description

The method uses the UCI Learning repository data located at Germany for analysing the healthy subjects. The data are classified as two different types of kidney classes such as kidney with stone and kidney without stone. The major parts includes Training set (), Test set (), and Validation data () for finding the classification accuracy of the machine-learning algorithm. The trails are categorized the test set into class 0 or 1 for the FFBN classification system. The figure 1 describes the normal and abnormal kidney images from UCI database.

(a) (b) (c)

Figure 2: a) Normal kidney image b) Kidney with cyst c) kidney with stone

B. Evaluation Metrics

In this section, the outcomes of the proposed method are evaluated by different parameters such as accuracy, sensitivity, specificity, False Positive Rate (FPR) and False Negative Rate (FNR).

The metrics are used for this parameters are described as True Positive (TP), True Negative (TN), False Positive (FP), False Negative (FN).

Sensitivity: Sensitivity is described in Eq. (8) as ratio of TP number to the addition of both TP and FN.

$$Sensitivity = \frac{No.ofTP}{No.ofTP + No.ofFN} \times 100 \qquad (8)$$

Specificity: This parameter can be explained as the ratio of total number of TN to the total number of both TN and TS in Eq. (9)

$$Specificity = \frac{No.ofTN}{No.ofTN + No.ofFP} \times 100 \qquad (9)$$

Accuracy: By using the measure of sensitivity and specificity, accuracy can be evaluated. These measurements can be explained in the following Eq. (10).

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \times 100 \qquad (10)$$

False-positive rate: FPR is used to predict the proportion of all negative outcomes produces the positive test outcomes which is described in Eq. (11). In addition, the FPR is also represents as false-acceptance rate (FAR)

$$FPR = \frac{FP}{FP+TN} \times 100 \qquad (11)$$

False-negative rate: The negative test outcomes are yielded by the proportion of positive outcomes that are explained in Eq. (12). Moreover, the false-rejection rate (FRR) is the other name of FNR.

$$FNR = \frac{FN}{TP+FN} \times 100 \qquad (12)$$

C. Performance Analysis

In the following section, various existing methods are compared with the PSO- ANN method for validating the performance results in kidney image classification. The method considered half of the data for training and remaining half for the testing process (i.e. 50-50 sample data).

Table 1 describes the values of various metrics for the PSO-ANN with existing and proposed methodologies.

Table 1: Confusion Matrix Values of Proposed and Existing Methods.

Perfor-mance Measur-e	ANN	GA+ ANN	KNN	Naive Bayes	PSO+ANN
TP	0	1.6468	0	0	0.1435
TN	4.2505	1.2546	6.4116	5.9157	6.8218
FP	1.8892	0.784	0	0	0.1782
FN	1.4169	3.294	1.4796	1.3652	0.8565

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The sensitivity, specificity and accuracy values computed from the above confusion matrix values are given in Table 2. Table 2 shows that the specificity value is 100% for techniques like KNN and Naive Bayes algorithms, thus showing the better classification effectiveness of the proposed method.

Table 2: Sensitivity, Specificity and Accuracy Values of Proposed and Existing Methods.

Performa-nce Measure	ANN	GA+ANN	KNN	Naive Bayes	PSO+ ANN
ACC	0.5625	0.5625	0.8125	0.8125	0.8706
SPEC	0.692308	0.615385	1	1	0.97029
SEN	0	0.333333	0	0	0.57176

The experimental results of Accuracy, Sensitivity and Specificity are shown in the Fig. 3, Fig. 4 and Fig. 5 respectively.

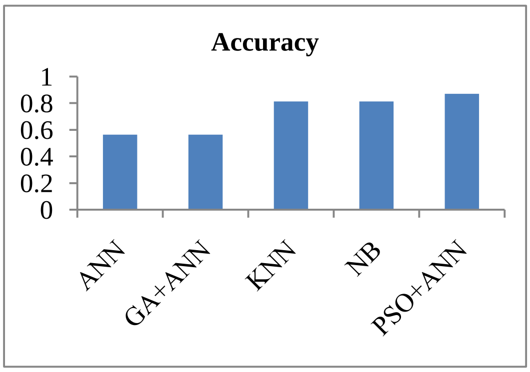

Figure 3: Accuracy values

While analyzing classification accuracy values, the proposed PSO-based ANN provides 87%, whereas GA-ANN and ANN give 56% and KNN and Naive Bayes give 81%.

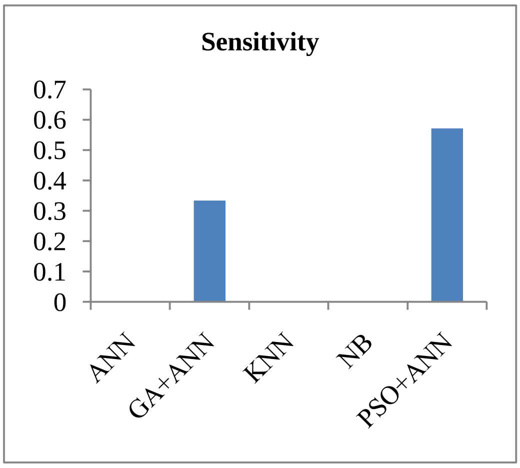

Figure 4: Sensitivity values

While analyzing classification sensitivity values, the proposed PSO-based ANN provides 57%, whereas GA-ANN gives 33% and ANN, KNN and Naive Bayes gives 0%.

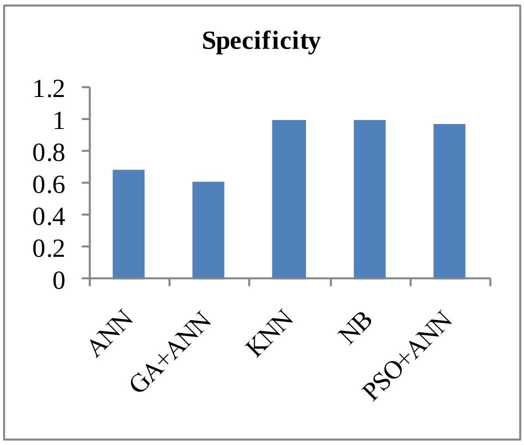

Figure 5: Specificity values

While analyzing classification specificity values, the proposed PSO-based ANN provides 97%, whereas GA-ANN gives 61%, ANN gives 69%, KNN and Naive Bayes gives 100%.

Thus, the performance outcome of the proposed strategy is markedly better in terms of accuracy, sensitivity and specificity measures and outperforms all the existing methods.

The FAR and FRR results of the proposed and existing methods is shown in the Table 3.

Table 3: FAR and FRR Values of Proposed and Existing State-of-the-Art Methods.

Metrics	ANN	GA+ANN	KNN	Naive Bayes	PSO+ANN
FRR	0	0	1	1	1
FAR	1	0.8571	0	0	0

V. CONCLUSION

In this approach, to classify the US kidney images, an effective abnormality classification method based ANN is presented. The outcome of the both proposed PSO-ANN approach and existing methods are evaluated by using metrics such as Sen, Spec and Acc for abnormal classification. The accuracy obtained by the proposed PSO-ANN method is around 87%, whereas the existing methods offers less than proposed one. From the results, it is clear that the proposed ANN works better than all other existing methods for classifying the kidney images. In the future, the method will concentrate for improving the accuracy by using different classification techniques in multi-label classifications of kidney images.

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