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Classification Of Kidney Disorders From Ultrasound Images Using Adaptive Neuro-Fuzzy Inference System

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Abstract

A computer-aided system is proposed for automatic classification of Ultrasound Kidney diseases. Images of four classes: Normal, Cyst, Renal Failure and Angiomiolipoma were considered. A set of statistical features and another set of multi-scale wavelet-based features were extracted from the region of interest (ROI) of each image and the principal component analysis was performed to reduce the number of features. The selected features were utilized in the design and training of a neural network classifier. A correct classification rate of 92% has been obtained using the multi-scale wavelet-based features

Keywords:. Ultrasound kidney images; Feature Extraction; Adaptive Neuro-Fuzzy Inference System; Discrete wavelet transform

1 Introduction

In recent years, great advances have been made in automated systems for detecting kidney diseases using ultrasonic systems which allow a greater amount and quality of information to be extracted during imaging the patients. The use of feature extraction, image analysis and pattern recognition techniques for classification is most suited to the evaluation of global conditions (e.g. failure, stone, tumor, and cyst).

The present paper describes an automated system for analyzing and classifying ultrasound kidney images. The system starts with capturing the ultrasound kidney image and identifying the region of interest. Image Preprocessing techniques are also employed to improve image quality and reduce noise. Discrete Wavelet Transform (DWT) was used for feature extraction as it has potential capacity in classification problems. Moreover, statistical features were extracted for the comparison purposes. Feature extraction with DWT yields to a large number of features being extracted, so the ANFIS technique was employed as being efficient in selecting the optimal features. The last stage in the system is the classifier. An adaptive nuero-fuzzy inference system designed and trained using the optimal features selected..

A kidney ultrasound may be used to assess the size, location, and shape of the kidneys and related structures, such as the ureters and bladder. Ultrasound can detect cysts, tumors, abscesses, obstructions, fluid collection, and infection within or around the kidneys. Calculi (stones) of the kidneys and ureters may be detected by ultrasound.
A kidney ultrasound may be performed to assist in placement of needles used to biopsy (obtain a tissue sample) the kidneys, to drain fluid from a cyst or abscess, or to place a drainage tube. This procedure may also be used to determine blood flow to the kidneys through the renal arteries and veins. Kidney ultrasound may be used after a kidney transplant to evaluate the transplanted kidney.

However, diagnosis of kidney diseases and abnormalities using ultrasound demands decision from experts as US images suffer from speckle noise. Speckle has variation of gray level intensities, where ranging from hyper-echoic to hypo-echoic and the presence of this noise makes analysis of US images more complex .Therefore, to enhance quality of these images, some image processing techniques are usually applied for better understanding of hidden information as well as for extracting some parameters or features that will be useful for diagnosis of the images.

Since the ultrasound images contain speckle noise, it is better to cut or remove any unwanted region. Our study has performed feature extraction based on two main features, one is intensity histogram features and the other is Gray Level Co-Occurrence Matrix (GLCM) features. For intensity histogram analysis, five features were selected namely mean, variance, skewness, kurtosis and entropy. GLCM is a statistical method that considers spatial relationship of pixels and it is also known as gray-level spatial dependence matrix. The spatial relationship is defined as pixel of interest and pixel to its immediate right (horizontally adjacent). Each element (I, J) in the resultant

GLCM is simply the sum of number of times that the pixel with value I occurred in the specified spatial relationship to a pixel with value J in the input image .

The characteristics of the designed classifier were investigated and optimized for both best performance and highest classification rate . Fig. shows a block diagram for the proposed system.

The paper is organized as follows: Section B describes the database used and the kidney diseases considered in the present study. Image preprocessing techniques are explained in Section C. Sections D and E present the feature extraction and feature selection techniques utilized, respectively. The classification stage is explained in Section F where an adaptive neuro-fuzzy inference system is utilized. Section G gives the concluding remarks.

2. Data Collection

Sixty-Six ultrasound kidney images were obtained from ULTRASCAN CENTRE – Ernakulum, Cochin, Kerala, India (http://www.ultrasoundimages.com/kidneys.htm) and Ultrasound Guide for Emergency Physicians-Johns Hopkins University Department of Emergency Medicine (http://www.sonoguide.com/renal.html) ; it includes a collection of images for normal kidney and kidney with multiple kinds of diseases such as:

- Angiomyolipoma (Tumor): These are the most common benign tumor of the kidney and are composed of blood vessels, smooth muscle cells and fat cells.
- Renal failure: It is a medical condition in which the kidneys fail to adequately filter waste products from the blood.
- Cystic kidney disease: it is a cystic genetic disorder of the kidneys

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- Normal Kidney: In normal all the functions are doing without any failure.

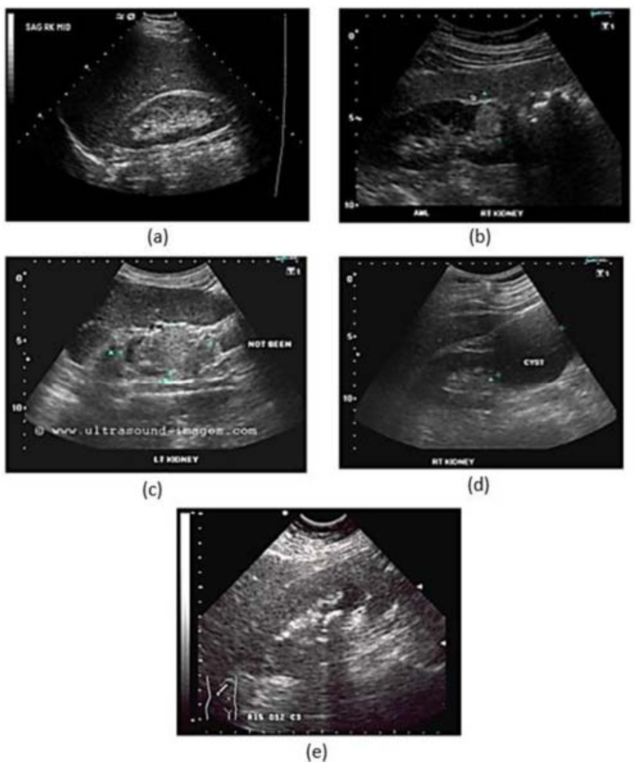
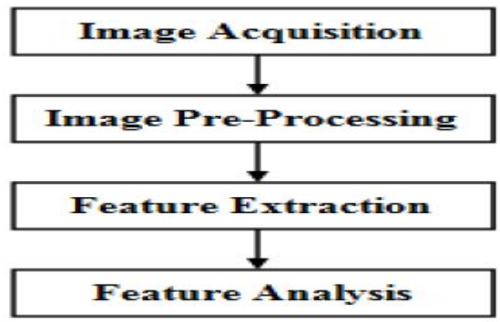


Fig:Kidney ultrasound images (a) Normal, (b) Kidney with tumor, (c) Kidney failure, (d) Kidney with cystic lesions, and (e) kidney with stone

3. Image Selection

Before analyzing images based on their feature extraction, pre-processing methods were performed to all kidney US images. Fig shows the pre-processing techniques applied to US images. Firstly, the images were cropped according to their region of interest (ROI). Deleting and removing complicated background will speed up further image processing. After cropping the ROIs, the kidney contour detection was performed.



Block diagram of the system

In this section, we describe materials and methods which are used throughout the experiment. Fig below shows the block diagram for kidney disorder classification system, starting with ultrasound image acquisition, image preprocessing, feature extraction and disorder classification.

A. Region-Of-Interest (ROI)

The first step in image preprocessing is to determine the region of interest (ROI). It will improve the speed and accuracy of classification process by selecting only the kidney and removing unneeded details like patient and scan information. Previous researches have proposed automated ways to get the ROI [5] nevertheless, in the present work, a rectangular ROI of size 256x256 was obtained manually by cropping the kidney image to simplify the process and limit the possibilities of errors. The ROI size of 256x256 pixels was chosen as being suitable for both longitudinal and transverse kidney images. Fig shows a normal kidney image with outlined ROI area.

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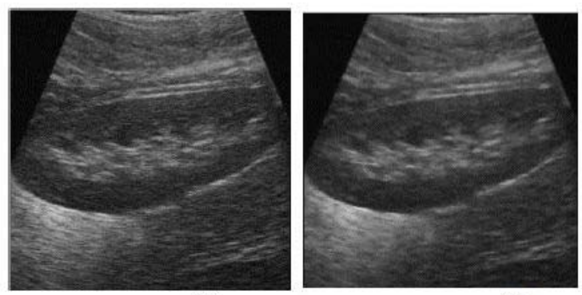
B. Image Acquisition

Kidney US images taken for analysis were obtained by using ALOKA ProSound F75. 20 images were taken for each group of kidney images to be extracted.

C. Image Pre-processing

Before analyzing images based on their feature extraction, pre-processing methods were performed to all kidney US images. Fig. 2 shows the pre-processing techniques applied to US images. Firstly, the images were cropped according to their region of interest (ROI). Deleting and removing complicated background will speed up further image processing. After cropping the ROIs, the kidney contour detection was performed.

Fig. Normal Kidney Image with outlined ROI



(a) (b)

Fig.ROI of Kidney image (a) Original Image, (b) Wiener filtered image

D. Speckle Field

To improve the quality of ultrasound kidney images, image-preprocessing techniques have been adopted. Three filters were applied and their performance was compared and evaluated in terms of entropy. These are: Wiener, Histogram Equalization and Median Filter.

1. Wiener Filter

Wiener filter is used to reduce the noise present in the image Fig. shows the output image after using Wiener filter.

2. Histogram Equalization

Histogram equalization is used to improve the visual appearance of an image by adjusting the image histogram Fig. shows the results of applying histogram equalization.

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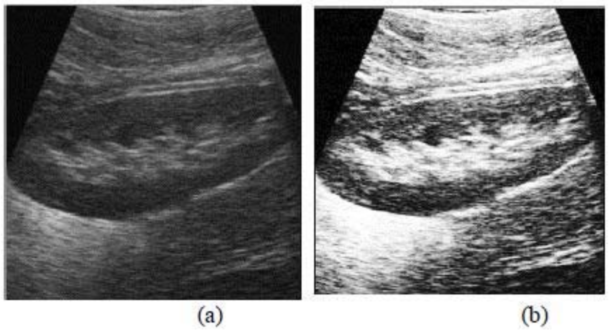

Fig. ROI of Kidney image (a) Original Image, (b) output of histogram equalization

3. Median Filter

Median Filter helps in reducing mainly speckle and salt and pepper noise. Fig. shows the resulting image after using a 3 x3 median filter.

The results showed that Median filter gives the best performance especially if the evaluator is concerning more on the kidney edges than the whole image.

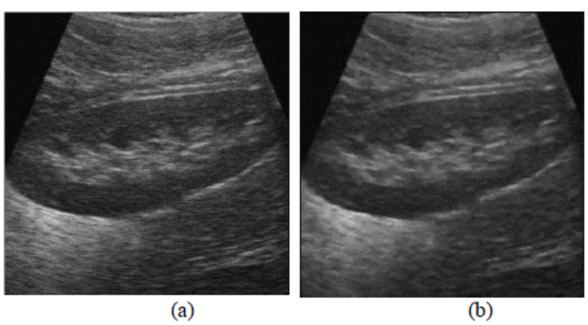

Fig . ROI (a) Original Image, (b) output of Median Filter

E. Feature Extraction

For intensity histogram analysis, five features were selected namely mean, variance, skewness, kurtosis and entropy. By describing the discrete image as *u(m,n)*, and *NR* is the total number of pixels in kidney region,mean,variance, skewness, kurtosis and entropy can be estimated .

Statistical features is one of the early methods proposed in image processing. The gray level co-occurrence matrix (GLCM) of the ROI was used .The following features are extracted from the GLCM of the ROI kidney images using MATLAB: Energy, Entropy, Contrast, Homogeneity, Maximum probability and correlation.

- Energy is a measure of local homogeneity .
- Entropy measures the average, global information content of an image in terms of average bits per pixel. As the magnitude of entropy increases, more information is associated with the image.
- Contrast defines the difference between the lightest and darkest areas on an image.
- Homogeneity is the state or quality of being homogeneous, biological or other similarities within a group.
- Correlation is a measure of the strongest of the relationship between two variables.
- Mean are used synonymously to refer to one measure of the central tendency either of a probability distribution.
- Standard Deviation is a measure of the dispersion of a set of data from its mean.
- Skewness is a measure of the asymmetry of the probability distribution of a real-valued random variables about its mean.

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- Kurtosis is the measure of the tails of a frequency distribution when compared with a normal distribution.

4. Discrete wavelet Transform

The discrete wavelet transform (DWT) is a multi-resolution analysis technique that analyzes the signal by decomposing the signal into its coarse and detail information, this is accomplished by using successive high-pass and low-pass filtering operations.

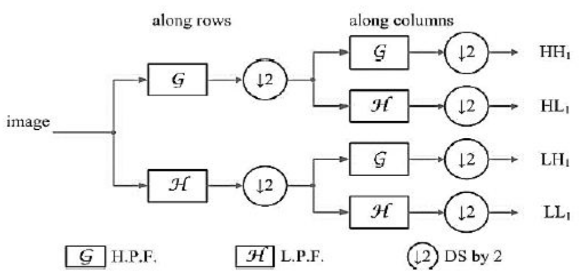

Fig. One level of the DWT transform for 2D signal

F. Feature Selection

The Adaptive neuro-fuzzy inference system technique was used frequently in this work for feature reduction in classification problems with ultrasound images [1], [5]. ANFIS was also used in conjunction with DWT in other object classification problems like face recognition . In this work, ANFIS helps in reducing the feature vector dimension obtained from DWT of ultrasound kidney images.

Using MATLAB, the first step in this procedure results in a covariance matrix of size 32x32. Second step gives an eigen vector of 32 values i.e. the eigen values .

- Specificity= true negatives /(true negative + false positives)

G. Neural Network Classifiation

Using "NeuralBuilder" module in "NeuroSolutions" software provided by "NeuroDimension", a multilayer neural network with two hidden layers with 10 nodes each was designed. Five output nodes were used to produce the following output encoding for the five kidney image classes-10000 for Normal, 01000 for Failure 00100 for Stone 00010 for Tumor and 00001 for Cyst. A Sanger´s rule and sigmoid activation function were found suitable for the classification purpose. A mean square error value of 0.05 was used to stop the learning process.

5. Building and Training ANN

Network characteristics like number of hidden layers, processing elements in each layers, optimization method and learning rule are customizable and could be adjusted for getting better learning rate and less mean square error (MSE) which is an important measure of network performance. Different topologies of neural networks were used to reach the best results.

Optimal results were obtained when the number of processing elements in the first hidden layer is 3 nodes and in the second hidden layer is 6 nodes.

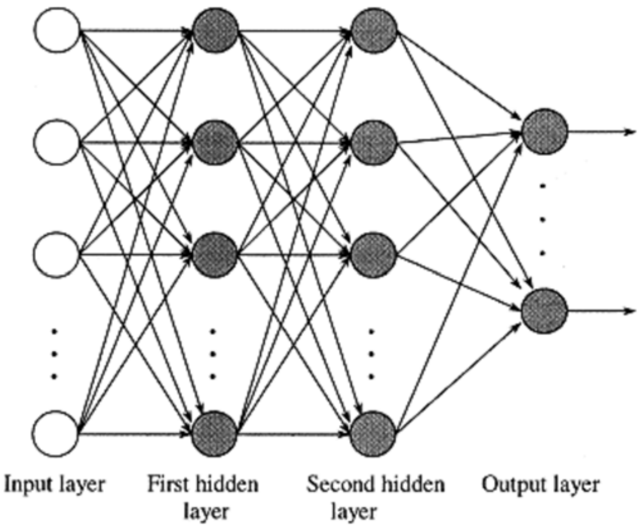

Fig. . Multilayer ANFIS with two hidden layers

Training was performed using the hold-out method where 50% of the data were used for training the classifier and 50% for testing [18]. Each set of features was used separately and the results were compared.

A correct classification rate of 95% was obtained using statistical features; on the other hand, 97% of the images were correctly classified when trained with wavelet features.

- Sensitivity= true positives/(true positive + false negative)
- Specificity= true negatives /(true negative + false positives)

H. Conclusion

- In this paper, an automatic system for the detection and classification of kidney diseases has been developed. The system consists of five main parts: ROI segmentation, image preprocessing, feature extraction, feature selection and classification. ROI segmentation was performed manually with the help of the physician by cropping. Image preprocessing was carried out using three types of filters: Wiener filter, Median filter and Histogram Equalization filter. The results showed that Median filter gives the best performance. Two sets of features were extracted using two different features extraction techniques. These are statistical-based features and the multi-scale wavelet-based features. Feature selection was achieved using the principal component analysis approach. A multilayer feed forward neural network utilizing the back-propagation algorithm was used for classification purpose. It has been shown that the highest classification rate was obtained using the multi-scale wavelet-based features. A correct classification rate of 97% has been obtained which is comparable to similar neural networks classifiers used in [1], [2]. The results are encouraging and promising. Further work is required to apply the suggested methodologies to a larger data set with a wide spectrum of kidneys disorders and to develop a complete intelligent system that can be used as an assistant tool in automatic classification of ultrasound kidney images. Improving the classification accuracy is a subject of a current investigation which aims to develop a complete automatic kidney images classification.

Image Class	Statistical Features		Wavelet- based Features	
	Classification Rate [57/60] (95%)		*Classification Rate* [59/60] (97%)	
	Sensitivity	*Specificity*	*Sensitivity*	*Specificity*
Normal	[10/10] (100%)	[48/50] (96%)	[10/10] (100%)	[50/50] (100%)
Failure	[10/10] (100%)	[50/50] (100%)	[10/10] (100%)	[50/50] (100%)
Stone	[10/12] (83%)	[48/48] (100%)	[11/12] (91%)	[48/48] (100%)
Tumor	[10/10] (100%)	[49/50] (98%)	[10/10] (100%)	[49/50] (98%)
Cyst	[17/18] (94%)	[52/52] (100%)	[17/18] (94%)	[52/52] (100%)

TABLE III. COMPARISON OF THE CLASSIFICATION RESULTS

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