Effective Segmentation Approaches for Renal Calculi Segmentation

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Abstract: ***US Images are a commonly used tool for renal calculi diagnosis, although it is time consuming and tedious for radiologists to manually detect and calculate the size of the renal calculi. It is very difficult to properly segment the US image to detect interested area of objects with the correct position and shape due to speckle formation and other artifacts. In addition, boundary edges may be missing or weak and usually incomplete at some places. With that point of view, the three proposed methods have been developed for renal calculi segmentation.***

Keywords: Ultrasound Kidney Image-ANFIS with Genetic Algorithm-Watershed-Active Contour**.**

1. Introduction

The main objective of this work is to assist the clinicians in successful detection of the renal calculi in US Kidney images. The advantages of US imaging are of low cost and minimal discomfort but the images are relatively poorer in quality. So the image analysis in general is challenging task due to data composition described along with speckle noises. These speckles are apt to mask the presence of low contrast lesion and reduce the ability of a clinician to interpret the actual information in the image.

The first proposed methodology called Effective Segmentation of Renal calculi Adaptive Neuro Fuzzy Inference System (ESRANFIS). The second proposed methodology called, Inner Outer Regions based new Enhanced-Watershed Segmentation method (IOREWS) effectively segments and detects the calculi using enhanced watershed transformation along with ANFIS approach. An effort has been taken to make the detection accuracy of renal calculi area high in terms of relative error which the previously proposed techniques suffer. Hence, to overcome these drawbacks, a third new Region Indicator with Contour Segmentation (RICS) method is proposed.

2. Related Works

Medical image segmentation, a critic step for most subsequent image analysis tasks, is to delimit the image areas representing different anatomies. Segmentation of the abdomen, in particular, is often a challenging task due to the considerable overlap of soft tissues by [1]. Since intensity-based methods have met with limited success for abdominal segmentation, texture segmentation, which makes use of statistical textures analysis to label regions based on their different textures, has attracted our attention. In this approach, low-level features based on texture information, that is expected to be homogenous and consistent across multiple slices for the same organ, are mostly used to perform automatic image analysis in the medical imaging field investigated by [2].

Among various image segmentation methods, the Seeded Region Growing (SRG) algorithm, originally proposed by [3], is a fast, robust, parameter-free method for segmenting intensity images given initial seed locations for each region. In SRG, individual pixels that satisfy some neighborhood constraint are merged if their attributes, such as intensity or texture, are similar enough. The seed location, an optimal threshold value and a similarity measure need to be determined either manually or automatically.

Region-based methods focus attention on an important aspect of the segmentation process missed with point-based techniques.. If we use not the original image but a feature image for the segmentation process, the features represent not a single pixel but a small neighborhood, depending on the mask sizes of the operators used. At the edges of the objects, however, where the mask includes pixels from the object and the background, any feature that could be useful cannot be computed. The correct procedure would be to limit the mask size at the edge to points of either the object or the background [4].

For kidney tumor segmentation, the region-growing method was applied from the center of the selected seed region as the starting point. Generally, the region-growing method performed the homogeneous test from the start pixel to the neighbor pixel using gray-level, texture, and color as acceptance criteria, and included or excluded the neighbor pixel according to the homogeneous test result until termination condition was satisfied [5].

To reduce the computation time needed for the segmentation process, a seeded region growing technique is used. Segmentation is performed in an attempt to reduce the large amount of information present in an image to a point where an automated process can recognize the objects of interest in the images. For example, computer-aided diagnosis (CAD) for classification of focal liver tumors in sonography requires segmentation as a preprocessing step for successive texture analyses of the tumors [6]. However, effective segmentation is a difficult task for noisy images such as B-scan ultrasound images, because the boundaries of the tumors of interest can be fuzzy and has low contrast.

A study of quantitative evaluation of (semi)-automated segmentation of US images and showed that even manual segmentation of noisy US images is not straight forward. On the other hand, reliable semi-automatic segmentation methods offer the potential advantage of making the measurement process more consistent [7].

Watershed segmentation is a famous edge-based segmentation algorithm. The term "watershed" is a geographical one. In geography, a watershed line is defined as the line separating two catchments basins. The rain that falls on either side of the watershed line will flow into the same lake of water. This idea can be used in digital images. The image gradient can be viewed as an environment. The homogeneous regions in the image usually have small gradient values. Thus, they represent valleys, while edges represent peaks (edges have high gradient values). [8] proposed the immersion simulation algorithm for watershed lines calculation.

The region growing, snakes, watershed, and texture homogeneity assessment are well known approaches for segmentation and frequently applied to medical images **[9].**

3. ESRANFIS Segmentation Method

Effective Segmentation of Renal calculi Adaptive Neuro Fuzzy Inference System (ESRANFIS), effectively segments and detects the calculi using effective Adaptive Neuro Fuzzy Inference System (ANFIS) approach. Unlike other Artificial Intelligence enabled segmentation techniques, the proposed technique utilizes the ANFIS in two phases. One is for classification of normal and calculi-affected kidneys, which is a preprocessing phase in the proposed technique and another phase is to segment the renal calculi area in the classified renal calculi image.

In the first preprocessing phase of ESRANFIS method, various preprocessing operations are performed, edge pixels are detected by using Canny method and Genetic Algorithm (GA) is used to select the reference pixels before classifying the given image as normal or with renal calculi. The ANFIS system is used in the training process for classification. The testing process of the classification follows the same method and the classification accuracy is tested.

In the second phase of ESRANFIS method, various region parameters are determined and ANFIS is trained using those parameters to segment the renal calculi area. Then the testing process is performed. Here reference and testing images are compared and then morphological operation is performed to accurately detect the renal calculi area. Instead of directly performing calculi segmentation as done in the conventional algorithms, determining the calculi-affected kidneys and then segmenting the calculi leads to improvement in the accuracy of the technique. As a result of the aforesaid processing phases in the proposed technique, a remarkable rate of accuracy is achieved when working out with various US kidney images. Even though the first method achieves higher accuracy in calculi detection, the sensitivity and other measures should be still improved. So the second method is proposed to achieve improved results in sensitivity and other measures along with minimum relative error.

In the ESRANFIS renal calculi segmentation method, the Renal Calculi in the medical US kidney images is segmented using ANFIS. The classification and detection techniques are used to perform the segmentation in this method. When compared to other segmentation techniques, this method offers high accuracy result in segmentation. However, the method lacks in sensitivity and specificity measures.

A segmentation method with new region indicators and enhanced watershed transformation is proposed in the name of Inner-Outer Regions based Enhanced-Watershed Segmentation (IOREWS) method to overcome the aforementioned drawbacks in this work. The proposed method is implemented and the results are analyzed in terms of various statistical performance measures. The results show the effectiveness of proposed IOREWS method in segmenting the renal calculi and achieved improvement in terms of statistical measures. Furthermore, the performance of the proposed technique is evaluated by comparing with the other segmentation methods.

4. The IOREWS Segmentation

The proposed method performs four major processes, namely, (i) Preprocessing, (ii) Determining outer region indicators (iii) Determining inner region indicators and (iv) Enhanced watershed segmentation. The block diagram for IOREWS stone segmentation method is shown in Figure 1(i) and (ii).

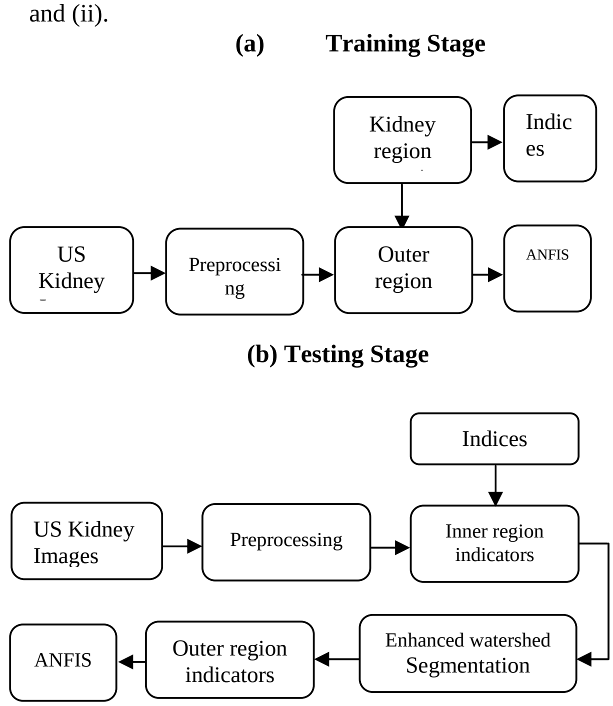

Figure 1: IOREWS Renal Calculi Segmentation Method

In this IOREWS method, the images are resized to 256 x 256 pixels. The resized images are given as input to the system. In Figure 4.1 (a), the noises in the training images are removed and the noise free image is given to the outer region indicators. The result of the outer region indicators is the pixel values, which are then given to the ANFIS system to perform the training process. In Figure 1 (b), the noises in the testing images are removed by preprocessing and the kidney centroid coordinates values are found by inner region indicators. The enhanced watershed algorithm is used to segment the regions and the outer region pixel values are found through the outer region indicator's procedure. Then the indicator pixel values results are used to perform the testing process through the ANFIS system.

5. The RICS Method

In the previous renal calculi IOREWS segmentation method, the Renal calculi have been segmented from the medical US kidney stone images using region indicators and modified watershed segmentation. But, the accuracy of stone detection in IOREWS method does not give adequate result. Moreover, the high complexity of the technique has given only less utility to the medical environment. Hence, to overcome these drawbacks, a new Region Indicator with Contour Segmentation (RICS) method is proposed. In this proposed RICS segmentation method, five major steps are followed to select the exact calculi region in the renal calculi images.

In the first and second stages, the region indices library and renal calculi region parameters are computed. Then, the image contrast is enhanced by the Histogram Equalization and the most interested pixel values of enhanced image are selected by the k-means clustering. The most interested pixel values are utilized to find the accurate calculi in the renal images. In the final stage, a number of regions are selected based on the contour extraction process. Subsequently, pixel matching and sequence of thresholding process are performed to find the calculi. In addition, the usage of ANFIS in supervised learning has made the technique more efficient than the previous techniques. Here, the utilization of contour reduces the relative error in between the Expert radiologist and the segmented calculi, which are obtained from the proposed algorithm. Thus, the obtained error is minimized when compared to the existing algorithm which results in high efficiency.

6. Results and Conclusion

The performance of IOREWS with ESRANFIS, SVM and NN using various statistical measures for average of 50 test images are given in Table 1.

Table 1: Statistical Performance measures of IOREWS, ESRANFIS and RICS

Method/ Measures	*SV*	*SC*	*NPV*	*MCC*	***ACC***
RICS	96.3	99.8	99.9	83.1	99.8
IOREWS	86.6	99.7	99.9	70.3	97.6
ESRANFIS	59.4	99.7	99.8	45.9	96.6

As shown in Table 1, the RICS method performance is better when compared to IOREWS, ESRANFIS, SVM and NN methods. The sensitivity measure of RICS method performance is highly deviated from the other methods, but the specificity measure of RICS is slightly deviated from specificity measure performance of other methods. In addition, the False Positive Rate (FPR) of RICS method is lower when compared to that of IOREWS, ESRANFIS methods. The FPR is the proportion of absent events that yield positive test outcomes. Moreover, the other measures like PPV, NPV, FDR and MCC have shown high performance result for RICS method.

By comparing the measures of all the proposed methods, the RICS method produces average results of 96.3%, 99.8% and 99.8% for sensitivity, specificity and accuracy respectively.

The results also demonstrates that the RICS method produces improved results in SV, SC, PPV, NPV, MCC and ACC measures. The FPR and FDR values are minimized compared with other three methods. The RICS method produces best results in terms of all measures. So it has been proved from the results that the RICS method is better in terms of sensitivity and all other measures compared to ESRANFIS, IOREWS.

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