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Proposed Seed Pixel Region Growing Segmentation and Artificial Neural Network Classifier for Detecting the Renal Calculi in Ultrasound Images for Urologist Decisions

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Abstract

The most common problem in the daily lives of men and woman is the occurrence of kidney stone, which is named as renal calculi, due to living nature of the people. These calculi can be occurred in kidney, urethra or in the urinary bladder. Most of the existing study in the diagnosis of ultrasound image of the kidney stone identifies the presence or absence of stone in the kidney. The main objective of the paper is to propose a computer aided diagnosis prototype for early detection of kidney stones which helps to change the diet condition and prevention of stone formation in future. The proposed work is based image acquisition, image enhancement, segmentation, feature extraction and classification, whereas in initial stage, ultrasound of kidney image is diagnosed for the presence of renal calculi stone and its level of growth measured in sizes. Seed pixel based region growing segmentation is applied in our work to localize the intensity threshold variation, based on the different threshold variation, it is categorized into a class of images as normal, stone and stone at early stages. The proposed segmentation is based on identifying the homogeneous regions which depends on the granularity features, therefore interested structure with different dimensions are compared with speckle size and extracted. The shape and different size of the grown regions are depending on the entries in lookup table. After completing the stage of region growing, region merging is used to suppress the high frequency artifacts in the ultrasound image. Once the segmented portion of stone is extracted and statistical features are calculated, which can be feed as feature selection by principle component analysis method. The extracted features are in input for artificial neural network classifier for achieving the improved accuracy compared to previous works. The expected output findings are based on texture feature values, threshold variations, size of the stone from the ultrasound kidney image samples with the support of clinical research center. The findings in our study and observation are based on correct estimate size of the stones, position of the stones in location of kidney; these findings are not performed in previous work. The enhanced seed pixel region growing segmentation and ANN classification helps to diagnose the presence or absence of renal calculi kidney stones, which leads to an early detection stone formation in the kidney and improve the accuracy rate of classification.

Keywords: Kidney Stone, Segmentation, Feature Extraction and Classification.

1. Introduction

The Kidney stones are one of the most common disorders of the urinary tract. Kidney stone problem occurs as a common problem to every men and woman in Malaysia, due to nature of living. A kidney stone termed as renal calculi is a solid piece of material that forms in a kidney when substances that are normally found in the urine become highly concentrated. Renal Calculi stone may occur in the kidney or travel down the urinary tract. The size of the stone varied from smaller, medium and larger size like golf ball, as per the diagnosis, if in early stages not diagnosed, growth is to higher. When the size of the stone is smaller, it may pass on its own, causing little or no pain during urination. A larger stone may get stuck along the urinary tract (which is the body drainage system to remove the waste) and can block the flow of urine, causing severe pain or bleeding. The urinary tract includes two kidneys, two ureters, a bladder, and a urethra. The kidneys are two bean-shaped organs, each about the size of a fist. In daily routine, the two kidneys process about 200 quarts of blood to produce about 1 to 2 quarts of urine, composed of wastes and extra water. The urine flows from the kidneys to the bladder through tubes called ureters. The bladder stores urine until releasing it through urination. When the bladder empties, urine flows out of the body through a tube called the urethra at the bottom of the bladder. The occurrence of renal calculi stones can be in the kidney, ureters or urinary bladders. Calculi are due to abnormal collection of certain chemicals like oxalate, phosphate and uric acid. Most of the previous study in diagnosis of Renal Calculi spots out the presence or absence of the calculi in the kidney. In this project we propose an algorithm to detect the renal calculi and to find the size of the calculi. It is more helpful to change the diet conditions. In this paper, we presented a method for ultrasound kidney image diagnosis for calculi and to find the size of the calculi using Advanced seeded region growing based segmentation. The treatment based ultrasonic image acquisition procedure on detecting the stone accuracy is not promising in the previous work, so current proposed work on computer aided diagnosis system will improve the accuracy of stone detection. Figure 1 illustrates the location of kidney stone in the bladder.

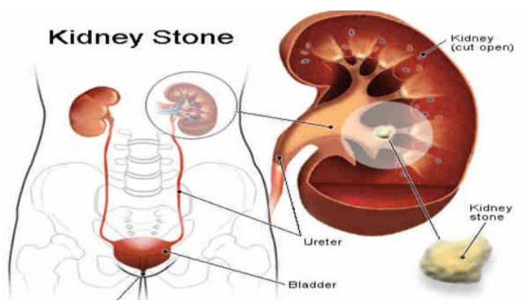

Fig 1 illustrates the kidney stone location (Image Acquired from Medical Imaging Modalities Article, 1999)

The paper is organized as follows: Section 2 explain the research challenges in the study. Section 3 describes the research objective for the research carried out in the paper. Section 4 explains in detail the background of research study. Existing works of machine learning approaches and commercial CAD system explained in Section 5. Proposed Machine learning approaches are explained in detail at Section 6. The expected outcomes of the proposed method are explained in Section 7. Finally conclusion is made in Section 8.

2. Research Challenges

The research paper has focused on the kidney image segmentation and diagnosis for stone detection and absence in the ultrasound images. First, the kidney moves within the patient owing to breathing, at several centimeters of amplitude and irrigation liquids are used during the operation. There are two constraints have a direct effect on image quality. Moreover, it is not uncommon to break some optical fibers, resulting in black dots on the image. Second, kidney stones have demonstrated different chemical compositions, resulting in different shapes, colors and textures finally; the system must be fast enough to work over the laser shooting rate on diagnosis of stone. The mentioned research challenges with constraints of image quality have been overcome the proposed study to detect the renal calculi stone. It is very difficult to interpret the ultrasound image. More experience and training is required to interpret the ultrasound images. Even human experts differ in the interpretation of ultrasound images. The available segmentation algorithms are general techniques and fail to detect the kidney from ultrasound image for stone detection. The manual methods of segmentation needs high attention of sonographer and also suffer from poor accuracy and time consuming. The proposed algorithm is based on the region-growing framework. The proposed model is used for segmenting the kidney contour from the ultrasound image for detection of kidney stones.

Research Questions:
Based on the research challenges, several research questions are framed to conduct the study:

- How the speckle noise is reduced in the kidney stone images, what design parameters are considered for the speckle reduction and optimize the image registration
- How region of interest is determined to extract the stone location of different sizes for segmentation.
- Extracting the local and global features, how many are determined to use for hybrid classification.
- Within the integration of Artificial Neural Network, what challenges are imposed to build the training and testing database?
- For improving the classifiers, how resulting classifiers are faithful with respect to the data i.e., how the dependences and independences of the data are represented correctly.

3. Research Objectives

Among all type of imaging modalities, ultrasound images play a crucial role, because they can be produced at video-rate and therefore allow a dynamic analysis of moving structures. Apart from that, the acquisition of these images is non-invasive, cheap, and does not require ionizing radiations compared to other medical imaging techniques. The research challenge of segmentation of anatomical structures in our proposed ultrasound imagery is a difficult task due to speckle noise and artifacts which are inherent in these images. Speckles in an ultrasound image were treated as noise and our proposed algorithm reduces the noise in the image. Speckle gives ultrasound images their characteristic granular appearance. It inherently exists in coherent imaging, including ultrasound imaging. Compare to existing works of reducing the speckle noise, we have proposed image enhancement approaches on noise reduction in this study. Due to the relatively low quality of clinical ultrasound images, a good ultrasound image segmentation and classification method needs to make use of all task-specific constraints or priors.

The main objective of the proposed system in the paper is to make contributions to a CAD system which can provide a “second opinion” to radiologists/urologist on a routine clinical basis. CAD helps in detection of kidney diseases and also in early detection of kidney stones which is based on segmentation and categorization of kidney images with stone sizes. The developed prototype in this study can helps in 1)Improving the quality of diagnosis 2) Increasing therapy success by early detection of Disease 3)Avoiding unnecessary biopsies 4)Reducing radiotherapist interpretation time 5)Improves the accuracy and reliability of detection.

- ✓ Design an enhanced filtering algorithm to reduce the speckle noise in ultrasound kidney image. Therefore proposed image enhancement is based on the process of digitization and preprocessing the kidney images to eliminate speckle noise for better visual quality.
- ✓ To design and implement kidney stone localization and detection system by seed pixel region growing segmentation method.
- ✓ Design a mathematical model of extracting the texture features from the extract renal calculi.
- ✓ To design and implement an ANN classifier approach to classify the level of stone from normal to medium to larger size.
- ✓ To validate the Performance of the prototype based on accuracy, correctness and completeness.
- ✓ The complete prototype is run for validation. It is a physical experimental of the prototype. Tasks include observation from urologist, comparing from the result of the kidney stone segmentation and classification with the diagnosis given by the clinical biopsies. At the end we will have percentage of accuracy of the system in all aspect of renal calculi observation the percentage of number of false positive detections, percentage of missing data and uncertainties, percentage of confidence of the classifiers respect to the data.

4. Background Study

Ultrasonic Image: Ultrasound (ultrasonography) is the use of sound waves to create an image on a video screen. A kidney ultrasound uses a handheld probe called a transducer that sends out ultrasonic sound waves at a frequency too high to be heard. When the transducer is placed on the abdomen at certain locations and angles, the ultrasonic sound waves move through the skin and other body tissues to the organs and structures of the abdomen. The sound waves bounce off the organs like an echo and return to the transducer. The transducer picks up the reflected waves, which are then converted into an electronic picture of the organs. Different types of body tissues affect the speed at which sound waves travel. Sound travels the fastest through bone tissue, and moves most slowly through air. The speed at which the sound waves are returned to the transducer, as well as how much of the sound wave returns, is translated by the transducer as different types of tissue. By using an additional mode of ultrasound technology during an ultrasound procedure, blood flow to the kidney can be assessed.

Computed tomography (CT) scans: The CT scan is an x-ray procedure that produces detailed cross-sectional images of your body. Instead of taking one picture, like a conventional x-ray, a CT scanner takes many pictures as it rotates around you. A computer then combines these pictures into an image of a slice of your body. The machine will take pictures of multiple slices of the part of your body that is being studied. CT scans do not show complete kidney structure well, but they can see larger tumors, and may be able to see if the tumor is growing into nearby structures. A CT scan may also find enlarged lymph nodes, signs of cancer spread to liver or other organs, or signs that a stone is affecting your kidneys or bladder [1].

Magnetic resonance imaging (MRI) scans: MRI scans use radio waves and strong magnets instead of x-rays. The energy from the radio waves is absorbed and then released in a pattern formed by the type of tissue and by certain diseases. A computer translates the pattern of radio waves given off by the tissues into a very detailed image of parts of the body. Not only does this produce cross-sectional slices of the body like a CT scanner, it can also produce slices that are parallel with the length of the body. A contrast material might be injected into a vein (same as with a CT scan). MRI scans are not used often to look for kidney stone [1].

Positron emission tomography (PET) scan: In this test, radioactive glucose (sugar) is given to look for the cancer. Because cancers use glucose (sugar) at a higher rate than normal tissues, the radioactivity will tend to concentrate in the cancer. A scanner can spot the radioactive deposits. This test can be helpful in spotting small collections of cancer cells. In some instances this test has proved useful in finding kidney stone that occurs commonly in current living style [1].

<u>Research Background on Machine Vision</u>

The most commonly used CAD systems detect cancer by analyzing a single view of the medical images. Most of the CAD programs have a two-step procedure to accomplish this. The first step detects suspicious locations inside the urinary tract area by machine learning techniques such as kidney stone of image enhancement techniques which include global approach &local approach. In the second step the image at these locations is segmented into regions and several features are calculated for each region. These features are being used to determine whether a lesion is benign or malignant. They are also used to eliminate false positive detections. There were related research performed in segmentation includes Global thresholding, Local thresholding, Edge detection, template matching, region growing, image subtraction & fuzzy techniques. The third step includes features extraction and selection where stone detection and classification is performed, most of the work performed in feature extraction includes global and local features such as shape, density, size are calculated. Final step is performed through classification, some of them are based on Bayesian networks learned on stone descriptions provided by radiologists or on features extracted by image processing. Other classifying techniques that are used for the diagnosis of kidney stones are Support Vector Machines, Artificial Neural Networks, Linear Classifiers and Association Rule based classifiers.

5. Existing Works

There are several existing approaches were made to detect the suspicious region in ultrasonic images. 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 [2]. 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 [3].Among various image segmentation methods, the Seeded Region Growing (SRG) algorithm, originally proposed by [4], 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. There a pixel is classified as an object pixel judging solely on its gray value independently of the context. This meant that isolated points or small areas could be classified as object pixels, disregarding the fact that an important characteristic of an object is its connectivity. 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 [5].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 [6].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 [7]. 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 [8].The term "watershed" is a geographical one. In geography, a watershed line is defined as the line separating two catchments basins. Thus, they represent valleys; while edges represent peaks (edges have high gradient values) [8]. Proposed the immersion simulation algorithm for watershed lines calculation. Initially, the image gradient is calculated using the Sobel operator [9]. In the immersion simulation algorithm, the image is viewed as a surface and the gradient local minimum of each region as a hole from which the water will rise up. The local minimum for each overlapped 3x3 block within the gradient image is calculated. Therefore only a few researches have directly examined video images. In this study, automated segmentation and classification scheme performs the function, without the need for an interaction from the user to diagnosis kidney stones presence, absence and early detection

Related Research Works on Machine Vision Techniques

a) Image Enhancement

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- ✓ **Global Approach:** Reassign the intensity values of pixels to make the new distribution of the intensities uniform to the utmost extent
- ✓ **Local Approach:** Feature-based or using non-linear mapping locally (example: Median filtering)

b) Image Segmentation

- ✓ **Global Thresholding:** Based on global information, such as histogram of the kidney image.
- ✓ **Local Thresholding:** Based on determining thresholding value locally and it can refine the results of global thresholding, and is better for stone detection than global thresholding.
- ✓ **Edge Detection:** Traditional method for image segmentation and it detects the discontinuity in ultrasonic images.
- ✓ **Template Matching:** Segments possible kidney stone from the background using prototypes
- ✓ **Region Growing:** Finds a set of seed pixels first, then grow iteratively and aggregate with the pixels that have similar properties
- ✓ **Fuzzy Segmentation:** The fuzzy techniques including fuzzy thresholding and fuzzy region growing; it can handle the unclear boundary between normal tissue and tumors
- ✓ **Wavelet Segmentation:** Based on Discrete Wavelet transforms, and using Haar wavelet, segmentation is processed.

c) **Feature Extraction**

Feature space can be divided into 3 sub-spaces: Intensity features, Shape features & Texture features.

d) Classification

- ✓ **Artificial Neural Network:** Construct non-linear mapping function as decision boundaries. Therefore it has 3 layers back propagation of NN and Radial Basis Function (RBF) network
- ✓ **Bayesian Classifier:** Naive Bayes classifier assumes that the presence (or absence) of a particular feature of a class is unrelated to the presence (or absence) of any other features.
- ✓ **Association Rule Based:** Based On Image data collection in database, it mines the data set by classes instead of mining the entire data set at once.
- ✓ **Support Vector Machine:** SVM takes a set of input data and predicts, for each given input, which of two possible classes the input is a member of, which makes the SVM a non-probabilistic binary linear classifier.

6. Proposed Method

The methodology has five distinct steps: pre-processing, seed pixel selection, region growing region merging of pre and post segmentation, feature extraction and ANN classifier engine development as shown in figure 2 below:

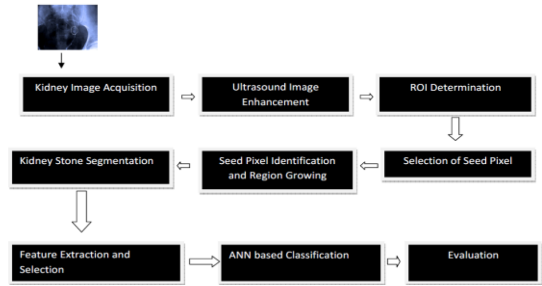

Fig 2 illustrates the Proposed Methodology of Kidney Stone Detection

Initially the ultrasonic image of kidney bladder is acquired and preprocessed by enhancement techniques, then system extracts texture features for each pixel in the Region of Interest. The proposed system uses the texture features, i.e. texture features are computed for pixels in each slice of kidney ultrasound image. This automatic region growing algorithm, takes a set of seeds as input along with the image. The kidney region to be segmented is marked by the seeds. By comparing all unallocated neighboring pixels to the regions iteratively grows the regions. The similarity measures used in this model are the difference between a pixel's intensity value, region's texture and local threshold. This technique is presented as, first preparation of lookup table of local statistics of all pixels to be used for initial region growing procedure, second grouping of pixels satisfying a specify homogeneity criteria and produce the homogeneous region, and finally merging the neighboring regions, which have similar intensity values with the tolerance level. The pixel with the minimum difference measured this way is allocated to the respective region. This process is repeated until all pixels are allocated to a region. The additional input to the seeded region growing process is it requires seeds. The segmentation process results are dependent on the choice of seeds. Noise in the image can cause the seeds to be poorly placed. The Next step in the pattern recognition system design cycle is feature extraction. Features were calculated based on first-order statistics, spatial gray-level dependence matrices, and spatial-frequency content. We have constructed two sets of features: statistical and spatial-frequency based. To determine the optimal subset of features, a third set was concocted by merging the two sets into a combined set of 14 features. As the features have different physical units, and thus substantial difference in variances, it was necessary to normalize them prior to feature selection. Therefore, we scaled each feature to have zero mean and unit variance. The normalized features were used in all subsequent analysis. Feature selection schemes are related to the type of classifier that will be used. Next features are feeded in to proposed hybrid classifier which combines ANN (Artificial Neural Networks). The selected ANN classifier is a feed forward multilayer perceptron with sigmoid hidden nodes. The ANN architecture consists of one hidden layer with fifteen sigmoid nodes, and an output layer with one sigmoid node, whose value indicates the level of stone sizes. Principal component analysis (PCA) has been implemented in order to reduce the size of the input feature vector. The output of the PCA is a reduced feature vector composed of seven features, providing the best classification performance. PCA eliminates features contributing to more than 3% of the total variation of the original feature set. Those features are normalized to zero mean and unit variance. Gradient decent, resilient back propagation, conjugate gradient and quasi-Newton methodologies were employed for ANN training in order to select the one with the best classification ability. The training procedure is terminated either when the training error is less than 10 or when 1000 iterations can be performed. The training error used is the mean square error which is the average squared error between the network output and the target output for all the training patterns (training) or the test patterns (evaluation). The two-fold cross validation method was used for the performance assessment of kidney stone (renal calculi)

The assessment of renal calculi classification performance in detection systems is performed using receiver operating characteristic (ROC) analysis. In this study, to determine the efficacy of each feature subset, its performance was estimated via ROC and FROC analysis.

By performing the calculi detection using seed pixel region growing correctly identifies the calculi area in the kidney stone images and it gives high classification, calculi detection accuracy. The segmentation accuracy of renal calculi achieved by the proposed method is adequate for using in various medical fields in future. The performance of the proposed method is evaluated by comparing the result of the expert's detection process.

7. Expected Outcome and Conclusion

The expected outcome of proposed study in this paper will be as follows:

✓ Enhanced Algorithm

The machine learning algorithm will be designed and enhanced by adding Seed Region Growing ANN and Texture Feature Extraction, new improved software is developed for kidney stone detection.

✓ Prototype

The experiment set up and implementation will be developed in MATLAB. The proposed framework when it is developed into prototype, will act as second reader for radiologist for comparing the results of the masses classification with the diagnosis given by the clinical biopsies. Percentage of accuracy is increased and number of false positive detections is decreased.

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