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An Approach for Kidney Stone Detection in Ultrasound Images

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Abstract

In this paper we propose a model to detect the presence of renal calculi in a renal ultrasound image. Kidneys are one of the most important organs of the human body. These organs are shaped in the form of a bean and they perform the most pivotal task of cleaning out the waste materials from the blood, and other lethal elements from the body, in the form of urine. The kidneys are made up of a large number of units of filtering called nephrons. Each nephron has two parts, a glomerulus and a tubule. The nephrons perform the whole process in two steps; the glomerulus percolates the blood and the tubule the essential substances back to the blood and removes the harmful wastes. Most kidney diseases damage the nephrons and so the ability of the nephron to remove the wastes is rendered useless. One such Kidney disease is presence of stone in kidney. Kidney stones are small stone like structure made by collection of minerals and salts. There are many types of kidney stones present like calcium stones, struvite stones, uric acid stones, cystine stones. These stones can be detected by use of medical imaging. Medical imaging is a field where different technologies are used to create a visual representation of human body for diagnosing and treating the diseases. In this case we have used ultrasound imaging for our purpose. Here we will preprocess the images followed by segmentation to partition the image into the area containing the stone and then determine whether stone is present or not.

Keywords; *Kidney stone disease, Segmentation, Spatial filtering, Ultrasound images of kidney, Median filter, Image enhancement*

I. INTRODUCTION

Ultrasound imaging for kidney is an inexpensive and non-intrusive system for diagnosing the kidney for abnormalities present in it like the shape, size and location of the kidney. Kidney stones are caused due to many reasons. The stone are categorized on the basis of their chemical constituents. Almost 80% of the kidney stones have calcium oxalate in them and they are the type of stones which create most difficulty for the human body. The kidney stones may be formed due to genetic factors and other factors like age, gender, body weight etc. But the formation of kidney stones depends majorly on the diet and the lifestyle of the individual. Also, kidney stones are caused by deficiency of enough water in the body. An individual who drinks less than eight to ten glasses of water are likely to develop kidney stones. In the ultrasound the stone is identified by the appearance of a shadow. The black color after the round shape like object gives us an idea that the stone might be present. But in the field of machine learning only this much information is not enough so we have to look for more features to identify the stone. But there is also one major setback in using ultrasound for detection of kidney stone as the ultrasound image is of poor quality. Speckle noise and several other disturbances in the image deteriorate the quality of the image. Therefore, several image enhancements methods are used to

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improve the quality of the image like reducing the speckle noise present in the ultrasound image. Speckle noise is a granular noise that is present in the images and corrupts the quality of the image. Reduction of speckle noise is necessary for detecting the kidney stone but sometimes the important and valuable information is lost in this process. So, we have to carefully design an algorithm so that precious data is not lost in the process. There are two reduction methods to reduce the speckle noise present in the ultrasound image: Image averaging and image filtering. Image averaging is done by averaging together a series of unrelated images in the spatial or frequency domain.

In Image filtering there are several other methods like spatial filtering which further consists of filters like linear, non-linear etc. Linear spatial filters initiate blurring and data loss while non-linear filters are used such as median and weighted median filter. Various filters in the spatial domain are proximity based, order statistic and wiener filter. Therefore, Image enhancement provides a very efficient way to determine the stones as it equips us with the minute details of the ultrasound image of the kidney which would otherwise be neglected if continued with the traditional methods of detecting the kidney stone.

Rest of the paper is organized as follows; Section II presents the literature review, section III presents the proposed model, section IV experimental evaluation and finally section V concludes the paper.

II. RELATED WORKS

In paper [1] authors suggested a way to detect kidney stones by making use of the semi-automatic segmentation approach. They have presented this method by the technique of seed region growing. Seed region growing is a very popular and effective algorithm for the identification of kidney stones in which a set of seeds are selected. In this set of seeds each seed could be a single pixel or a group of connected pixels. The seed growing algorithm then grows these seeds into regions by aggregating the adjacent pixels to it. This method is the best method for identification of the kidney stones since it is unaffected by speckle noise.

In [2] the authors have put forward the technique of fully automatic segmentation by using the method of symmetric analysis. This method basically involves three steps which are: detection of the stones, segmenting the area of the kidney and the last step of consisting of computing the area covered by the kidney stone.

In [3] the authors have come up with a technique of contour-based square Euclidean distance method (CSED) segmentation method. In this method the first step is preprocessing the ultrasound image of the kidney and then after this step the squared Euclidean distance is calculated between the centroid value of the training image considered and the centroid value of the selected image.

In [4] the authors have introduced several methods for image enhancements and after working out all these techniques they have finally came to the conclusion that morphological and median filtering provides best result when being compared to other techniques.

In [5] the authors have presented automatic region of interest generation regarding the ultrasound image of the kidney. This method consists of several other methods like reduction of speckle noise by making the use of gaussian low-pass filter, texture analysis of the ultrasound image by discovering its local entropy, finding the seed region, section of threshold, different morphological operations etc.

In [6] the authors have offered a method called region indicator contour segmentation method (RICS). In this method we see that the indices of the region are within the kidney region or not. If they are inside then those particular indices are included in the set of region indices otherwise, they are not. This method comes under the category of supervised learning method and is a little complex than the other methods but it provides the amount of

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accuracy which is required for the detection of the kidney stones.

In [7] the authors have proposed a technique for finding the kidney stones using MATLAB in which several filtering techniques are used to identify the kidney stone.

In [8] the authors have produced a method of wavelet-based filtering. Wavelets are established in mathematics for the examination of image structures that are multiscale in nature. Speckle filtering is by far the most vital step in preprocessing of the ultrasound image. The Discrete Wavelet Transform (DWT) provides us with a proper method of distinguishing the speckle noise present in an image. The task unsupervised image segmentation is completed with the help of fuzzy c means clustering. The demographic features present in the ultrasound image is drawn out by the given kidney stone image into a number of sub bands of different frequencies using the wavelet transform technique explained above and to further check the capability of these features as to how they will be able to identify the kidney stone present we make use of the technique of Back propagation Neural Network (BNN). These methods provide us better accuracy and better efficiency of determining the kidney stones.

In [9], Anushalin. P. S and Samson Isaac. J have proposed a technique for decline in the speckle noise and segmentation in the ultrasound image. This technique not only identifies different abnormalities in the kidney region but also provides enhancement of the image.

In [10] the researchers have offered a way of detecting the kidney stone images by partitioning the image into four distinct categories namely: normal, bacterial infection, cystic disease and kidney stones using a unique technique called Gray Level Co-occurrence Matrix (GLCM). This method is very efficient and different method of finding problems in the kidney region.

In [11], P. R. Tamilselvi and P. Thangaraj have offered a way of segmenting the image on the basis of seeded region growing and categorizing the kidney stone images according to their sizes using CAD system. Gabor function is used for acquiring a sharpened image which is optimized and smoothen properly with respect to both time and frequency.

We see that pH values drastically affect the formation of kidney stones in the human body. For example, an alkaline pH in the urine promotes the crystallization of stones containing calcium and phosphate while an acidic pH helps in formation of uric acid in the kidney leading to crystallization of cystine stones.

In [12] the authors have a proposed system in which the concerned doctor the region of the kidney stone in the given ultrasound image. This particular approach of finding the stone is partially automatic in which the medical professional selects an appropriate region of the kidney which is then analyzed to check whether the stone is present or not. Some selected features are then applied on cropped regions which have a chance of containing the kidney stone. Various features like entropy, correlation, contrast etc. are applied. Here a KNN classifier is taken into consideration for identification of stones. The total accuracy of the system proposed above is quite satisfactory and in order to improve the performance of this technique several other factors can be taken int account according to the need of the user.

In [13] researchers have brought about a new type of wavelet transform based method in which frequencies can be varied according to our need to develop effectiveness of noisy coefficients. The denoising efficiency is refined by making use of bilateral filter, various threshold schemes and Radial-dilation wavelet Transform (RADWT). Different kinds of wavelet transforms are used in the application of image processing such as denoising, blurring etc. those applications become invertible for which wavelet-transform is applied. The RADWT

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consists of following g features: two iterated channel filter banks and a rational dilation factor.

A non-linear filtering scheme based on RADWT is executed on the standard ultrasound images of the kidney. In this technique the decomposition of noisy image is done into several distinct sub-bands at different levels using the frequency resolution variation feature of the RADWT. High amplitude noise component is reduced to a major extent by using the Bilateral filter (BLF) and further in the next step the denoising efficiency is enhanced by thresholding.

In [14] the researchers have planned a method in which the very first step is the enhancement of the ultrasound image with the help of filters like gaussian and median and the concept of unsharp masking. After this step the morphological operations like erosion and dilation are performed on the image followed by segmentation of the image which is entropy based for the purpose of finding the region of interest and then finally applying different classification techniques like KNN and SVM for inspecting the kidney stone ultrasound image.

This technique starts with acquiring the ultrasound image first which takes an image from an external source. Initially we apply the median filter to the image and is basically used to the remove the noise for the image. Sharpening is achieved by un-sharp masking. At the initial stage the concept of image enhancement is very essential for upgrading the perception of the image information. Image enhancement helps to provide more minute details of the system.

In [15] a method is proposed in which three neural networks ae used each neural network having different properties and structure. Hence, we compare he performance of all three neural networks by considering factors like accuracy, total time taken, training data size etc. We will be using Learning vector quantization (LVQ), two layers feed forward perceptron trained with back propagation training algorithm and Radial basis function (RBF) networks for proper diagnosis of kidney stone disease.

We see that many wavelet transform based methods are used for preprocessing of the ultrasound image and they were somewhat successful in attainment of our goal but in methods like using a neural network, the results were satisfactory but not up to the mark and could be improved by considering several other factors.

In our proposed model we have used non-local means filter which gives better transparency and preserves the minute details of the image while in the previous models filters like gaussian and median were used which were not that efficient.

Previously contrast enhancement was done using histogram equalization but we saw that it gave deformed results so we applied gamma correction instead of histogram equalization and got better results as we were now able to clearly identify between the dark and the light region which aids us in identifying the kidney stone.

III. PROPOSED MODEL

In order to detect the presence of kidney stone (or renal calculi) in the images, obtained from renal ultrasound, we came up with the below mentioned method. It involves preprocessing and segmentation of the ultrasound image.

A. Noise Removal

Ultrasound images contain a lot of noise which makes it very difficult to spot any abnormality or detect any disease. Presence of various types of noises, shadows and motion blur is one of the most challenging artifacts when dealing with kidney ultrasound images. In order to overcome this problem we need to remove those noises and smooth the image, but at the same time making sure that the image does not lose important details. In order to do so we applied different filters.

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1) Median Filter: It is one of the most commonly used noise removal technique, sometimes also known as rank filter.

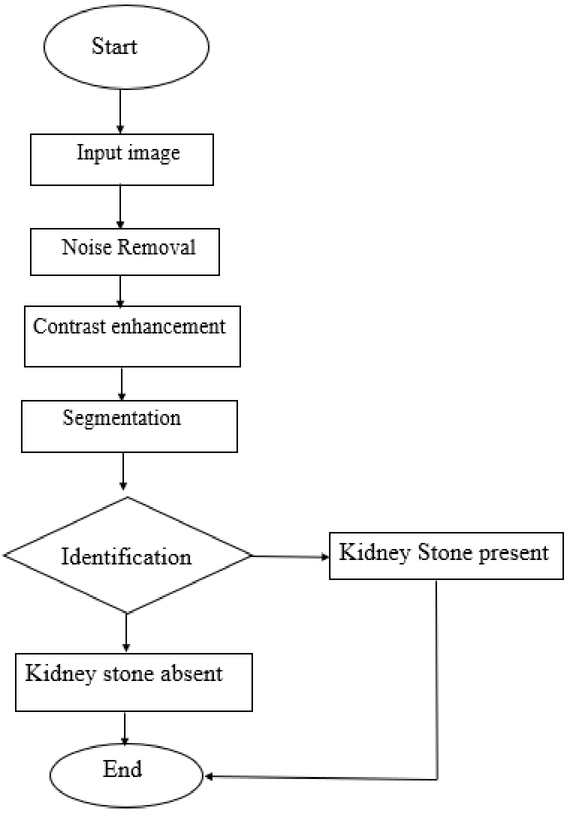

Figure 1. Flow chart describing the proposed model

It calculates the median value of the neighboring pixels of the target pixel, and replaces the target pixel with the calculated median value. Hence, its application removes the speckle noise in the image, but at the same time it blurs the image and eliminates the details.

2) Non-local Means Filter: This de-noising technique is different from the local means filter, which takes the mean of only the neighboring pixels. Non-local means filter takes the mean of all the pixels present in the image, based on how much a pixel is related to the target pixel. This type of filtering leads to better clarity and a lesser loss of details, compared to the median filter.

On comparing the results obtained by applying the above filtering techniques we found that the non-local means filter gives better results.

Figure 2. Original renal ultrasound image

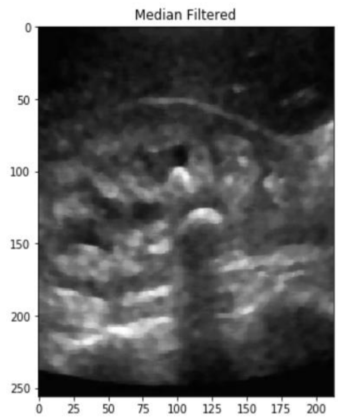

Figure 3. Image after application of Median Filter

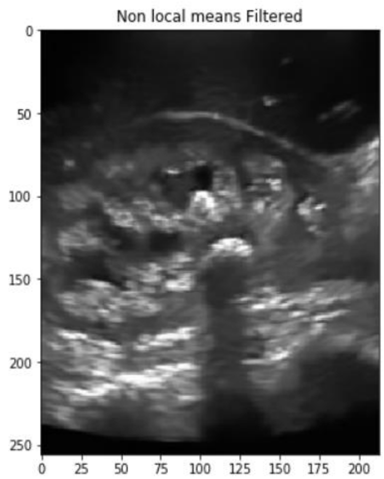

Figure 4. Image after application of Non-local Means Filter

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B. Contrast Enhancement

In order to improve the contrast and differentiate between various features we applied various contrast enhancement techniques on the filtered image, as mentioned below. This step ensures that features of the ultrasound image stand out more clearly.

1) Histogram Equalization: This contrast enhancement technique works by stretching the most frequently encountered intensity values in the image. It makes the low contrast regions in the image to gain more overall contrast. Basically, it spreads out or equalizes the intensity values for an image.

2) Gamma Correction: Compared to histogram equalization, which stretches out the intensity values, application of gamma correction increases the difference between the dark and light intensity values of an image. It basically makes the dark areas of the image darker and the light areas, lighter.

On applying histogram equalization we found that it distorts the ultrasound image by equalizing the intensity values, or making the pixels similar. Therefore, we implemented contrast enhancement by using gamma correction. Comparing the results from different values of gamma, we concluded that gamma of 0.2 is appropriate for our application.

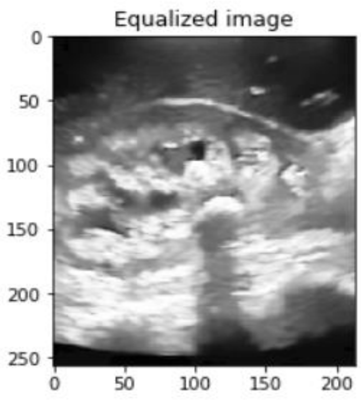

Figure 5. Image after Histogram Equalization

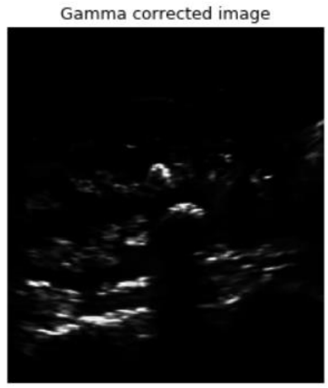

Figure 6. Image after application of Gamma Correction

C. Segmentation

Segmentation of an image involves the division of image into different regions. The goal of this step is to simplify the detection process by highlighting only the area of interest. In this application segmentation segregates the stone from other parts of the processed ultrasound image. In order to implement this step we have used the region growing algorithm. Region growing is a simple image segmentation technique which grows the region of interest from a point. It starts with the selection of a seed point, from where the region has to grow. In this case we are finding the seed point automatically. Taking seed point as the start this technique evaluates the neighboring pixels. If a pixel agrees to the seed, it is added to the region, which is basically a set of seed pixels. As soon as a new pixel is added to the region an updated mean is calculated and the above process is repeated until no more pixels are added to the region.

Algorithm for region growing segmentation involves the following steps,

i) Reading of the filtered and contrast enhanced image

ii) Selection of the seed point

iii) Calculation of mean

iv) Checking if a neighboring pixel is inside or outside the region

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v) Adding the pixel in the region if its intensity is close to the calculated mean

vi) Calculation of the new mean

vii) Repeating the above steps unless no more pixels are added to any region

IV. EXPERIMENTAL EVALUATION

A. Working Environment

The proposed work is implemented in Python 3, using libraries such as OpenCV, scikit learn and NumPy. A Graphical User Interface (GUI) has also been created as shown in Figure 10. The GUI shows the renal ultrasound image after various stages of processing. Once the user has browsed the image of renal ultrasound, they can observe the processed image, as they press the available buttons for different stages. When the Pre-Processing button is pressed, the ultrasound image goes through noise removal using Non-local means filter. On pressing the Image Enhancement button, contrast enhancement using gamma correction is applied on the filtered image. And when the user presses the Segmentation button, the enhanced image goes through segmentation, which in our case is implemented using the region growing algorithm.

B. Processing

Figure 7 shows the ultrasound images of two kidneys, one with kidney stone and the later without kidney stone. When we apply non-local means filter on these images, the noise present is significantly removed as shown in Figure 8. Further on applying gamma correction on the images we find that in the image with kidney stone, the stone is highlighted, while in the image without one, almost nothing can be seen. After the images are enhanced, segmentation is applied on the images. The result after segmentation indicates the presence or absence of kidney stone in the given ultrasound image.

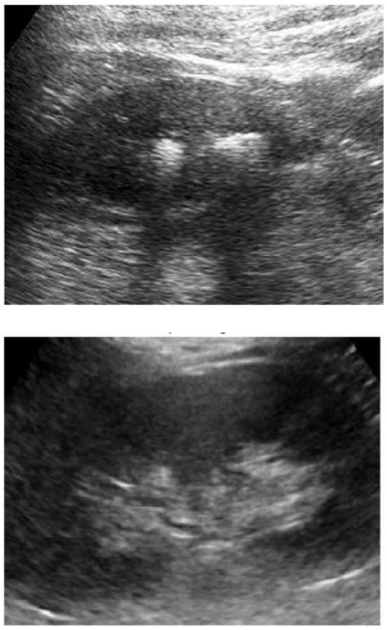

Figure 7. Image of Kidneys with and without stone

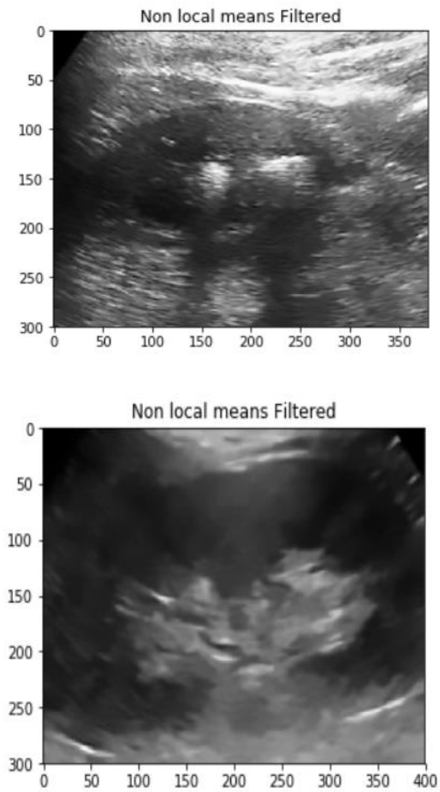

Figure 8. Filtered images with and without stone

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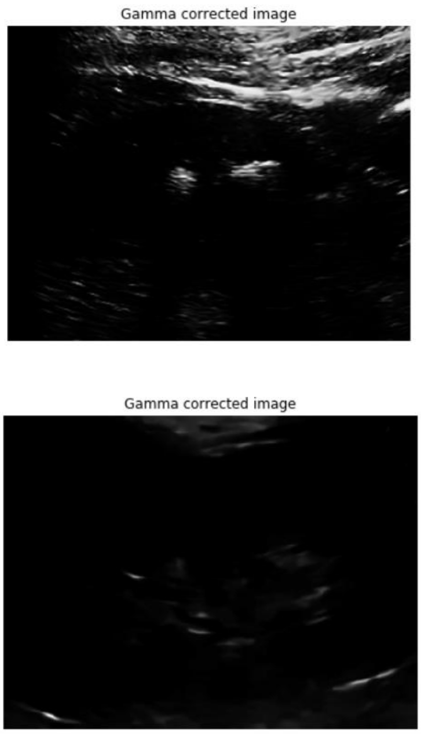

Figure 9. Enhanced images with and without stone

In Image 11, we see the histogram of the renal ultrasound image (with a kidney stone) before processing and after the processing is done. It clearly shows the elimination of unusable details in the image, and improved contrast between the kidney stone and the rest of the image.

C. Evaluation and Identification

If the region growing segmentation technique yields a result with a region then we can conclude that kidney stone is present, and if the results show no region then it indicates the absence of any renal calculi. As we can see in Image 10, the resultant image contains a region; this shows the presence of a kidney stone, whereas, the result of an image without a stone is completely blank.

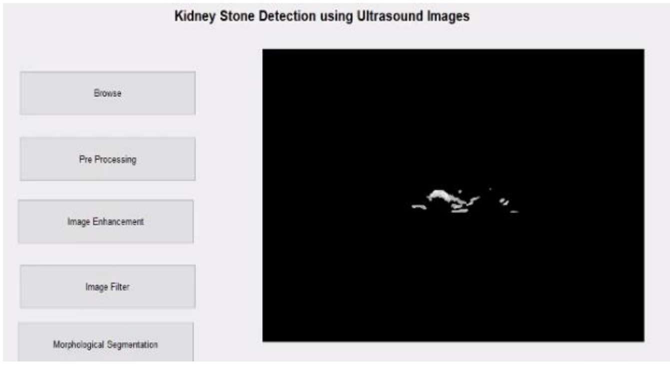

Figure 10. GUI showing the result after Segmentation

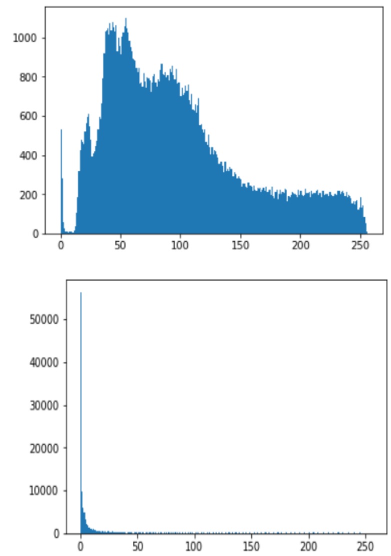

Figure 11. Histogram of ultrasound image before and after application of Gamma Correction

V. CONCLUSION AND FUTURE SCOPE

The proposed model gives satisfactory results for several renal ultrasound images, with and without kidney stones, collected from various websites. In the future we plan to induce techniques to extract various region parameters such as the size and location of the stone. These region parameters will further help us to identify the type of renal calculi, giving a clearer picture. Further, this work will be designed to evaluate real time input, obtained by placing biomedical sensors. Apart from this, we also plan to extend this system to address health issues in other parts of the body such as liver and gall bladder.

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