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Kidney Stone Analysis Using Digital Image Processing

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***Abstract*: Kidney stones are hard collection of salt and minerals often made up of calcium and uric acid. Majority of people with stones in kidney at initial stage do not notice and it damages the organs slowly. It is very important to detect the exact and accurate position of kidney stone for surgical operations. Ultrasound images normally consists of Speckle noise which cannot be removed by mankind. Hence we preferred automated techniques in detection of kidney stones in ultrasound images using median filter instead of gabor filter.**

***Keywords*: Kidney stone analysis, Median filter, Noise filtering Techniques using Matlab, Speckle noise removal, Ultrasound de-noising.**

1. Introduction

Kidney stones are on rise throughout the world and majority of people with kidney stone disease do not notice the disease as it damages the organs slowly before showing symptoms. Kidney is a bean shaped organ and present on each side of the spine. The main function of kidney is to regulate the balance of electrolytes in the blood. Formation of stones in kidneys is due to blockage of urine congenital anomalies, cysts.

Different types of kidney stones namely struvite stones, stag horn stones and renal calculi stones were analyzed. Kidney stone is a solid concretion or crystal formed in kidneys from dietary minerals in urine. In order to get rid of this painful disorder the kidney stone is diagnosed through ultrasound images and then removed through surgical processes like breaking up of stone into smaller pieces, which then pass through urinary tract. If the size of the stone grows to at least 3 millimeters, then they can block the ureter. This causes a lot of pain mostly in the back lower and it may radiate to groin. Classification of urinary stone is done based upon their location in the kidney (nephrolithiasis), ureter (ureterolithiasis), or bladder (cystolithiasis), or by their chemical composition.

The stone may be present inside minor and major calyces of the kidney or in the ureter. In medical imagining modalities, ultrasonography is used because it is versatile, portable, does not use ionizing radiations and is relatively of low cost. The major disadvantage of ultrasound image is that it consists of poor quality of images that has low contrast and multiplicative speckle noise thus making it a challenging task for detection of kidney stones. speckle noise present in the image degrades its quality which there by affects the interpretation and diagnosis.

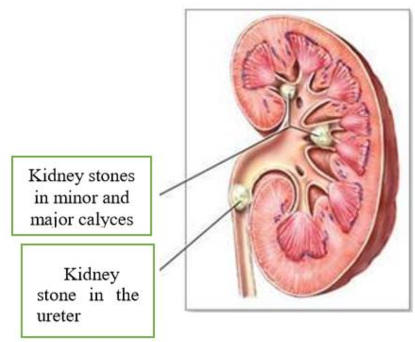

Fig. 1. Stone location in kidney

The kidney malfunctioning can be life intimidating. Hence early detection of kidney stone is essential. Precise identification of kidney stone is vital in order to ensure surgical operations success. The ultrasound images of kidney comprise speckle noise and are low contrast which makes the identification of kidney abnormalities a difficult task.

Thus to produce the efficient stone detection system, speckle filtering is one of the foremost and important step in the automated detection. This can reduce the erroneous detection which may occur due to knowledge variation of judging specialist preprocessing is then followed by segmentation and morphological analysis to detect the stone automatically.

Many researchers have contributed in the field of kidney stone detection by presenting various algorithms to detect the stone in the kidney from MRI images. Some researchers emphasize on strong and efficient segmentation. Some emphasized on strong and effective segmentation for accurate detection of stone. Once the image enhancement and noise reduction of the ultrasound image is done then the region of interest is obtained from the image. Akkasaligar et a1. [1] states that Gaussian low pass filter is the most optimal filter in differentiating cystic and normal kidney images while Hafizah et al. [2] states that choosing gaussian low pass filter at threshold value 0.7 to generate true kidney region of interest (ROI).

Many researches have contributed by presenting different algorithms in the field. Saini et al. [3] has stated that OTSU'S method is used for image segmentation and optimal global thresholding. Raja et al. [4] proposed that most fascinating pixel can be found by K-means clustering and contour based region selection process.

The main contribution of this paper is that the detailed process of detecting a kidney stone using ultrasound images is given. This paper also discusses various kidney stone detection techniques available in the existing literature with their advantages and disadvantages. Further, comparative study of various existing kidney stone detection techniques on the basis of different evaluation parameters used in the field of kidney stone detection is provided in this paper.

The rest of the paper has been organized as follows: In section 2 literature review is given which states important points made by different authors. In section 3, the steps for detection of kidney stone are given. In section 4, the parameters taken for evaluation are explained and a comparative study is made based on these parameters. In Section 5, shows result obtained after literature review and comparative study done in this paper. At last in section 6, we conclude how we improved quality of ultrasound images and how can it helpful at the time of surgical operations.

2. Literature review

This section provides a detailed overview of various existing kidney stone detection techniques using various images. Kidney stone detection in a human body is tedious task, as if wrongly detected this can lead to life threat. So in order to eliminate or reduce inaccurate detection of kidney stones many of the researchers have given their contribution by providing efficient kidney stone detection algorithms. The automation of kidney stone detection can reduce or approximately eliminate manual erroneous detection. This can help in better and accurate cure of the problem and can save human lives. Thus it has a direct impact on the society.

Mallala et al. [6] investigated a c-arm tomographic technique in their paper to develop three dimensional structure of kidney. The result of their experiments showed the ability to develop volume information for kidney stone detection but computerized Tomography (C.T) scans of the kidney have greater exposure to radiations than the regular X-ray radiations, particularly in the people who need repeated scanning and children who have less bones. Therefore, sadhegi et al. [7] discussed the radiographic method, which use x-ray films to diagnose stone faster and more accurately. The result of their paper shows almost 90% of urethral stones as dark and obscure.

Therefore, the disadvantage is that precise and accurate detection is limited. Furthermore, uric acid stones could not be observed and smaller stones are out of the field of view. Hence kidney stone detection is done in an improved method by using Doppler imaging sequence by Cunitz et al. [8]. This paper quotes that ultrasound is much better than computed Tomography (C.T).

Sun et al. [9] designed a rotational sono-probe that could take sonographic images of four equally separated angles with respect to an axis that is fixed and rotating. Calculation of renal volume manually is time consuming and unreliable. Their method is performed by minimizing some energy functions. Therefore, their automated method of calculating renal stone is precise and accurate as compared to that done manually. This three dimensional analysis is further used by Marsousi et al. [10] to improve kidney stone detection using automated methods. Their method automatically diagnoses and segment kidneys in "three dimensional abdominal ultrasound images".

Works of Tsao et al. [11] shows that detection of accurate position of kidney stone is very important for extracorporeal shock waves lithotripsy (ESWL). Since it uses shock waves to focus on renal stone in real time, the miss-hit of shockwave can cause damage or trauma to the tissues. Their research shows that ultrasonic images contain speckle noise which needs to be removed.

Rahman et al. [14] proposed reduction of speckle noise and segmentation of ultrasonic kidney images not only improves kidney stone detection but also enhances the quality of image. Furthermore, Vishwanath et al. [15] extracted some energy levels that give a hint of the presence of kidney stone in a specific location and then their paper applies multilayer perception (MP) and back propagation (BP) to increase the accuracy of type of stone detected to 98.9%.

3. Steps for detection of kidney stone

The first step is to collect the ultrasound images and forms a dataset. After collecting the dataset, the next step follows, Image pre-processing.

Image pre-processing: the aim of pre-processing is an improvement of the image data that suppresses unwanted distortions and enhances some image features. Noise removal using filter operations helps in intensifying or reducing specific image details thus making evaluation of the image easier and faster. It involves specific filtering, Image enhancement, edge filtering.

Ultrasound images consists of a lot of speckle noise. The presence of speckle noise disturbs the ultrasonic image. This disturbance leads to inaccurate detection of the stone which can cause harm to kidney tissues during surgery. So de-speckling of noise is a very crucial step of image pre-processing which improves the quality of image and enhances the information of required content.

- *Image Segmentation:* Image segmentation is the process of dividing a digital image into sets of pixels which are also known as super pixels. ROI model is used normally to detect the abnormal region based on clusters and centroids. Present step involves clustering algorithm, which categorize the input data points into different categories depending on their inherent distance from each other. It is used in detecting the region of interest.

- *Morphological analysis:* Morphing is the process of transforming object shapes from one form to other. Morphological operations are applied for smoothen the region of interest. At the time of structuring element morphological operations process the images depending on shapes. At the time of processing it removes the unwanted information known as pixels from the outside region of region of interest. It includes dilution and erosion.

Flow chart for steps involved in kidney stone detection,

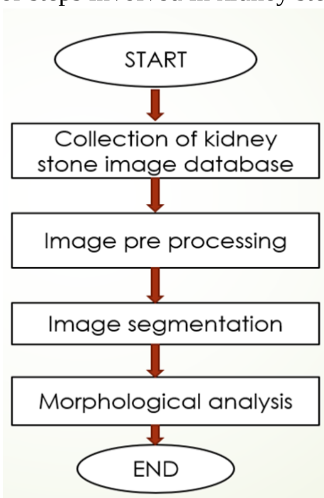

Fig. 2. Flowchart

4. Evaluation parameters

The overview of the parameters that are used for evaluating efficiency and correctness of the designed kidney stone detection algorithm.

Peak Signal to Noise Ratio (PSNR): It is the ratio of maximum possible value (power) and distortion noise power. It identifies the losses and lossy compression after reconstruction.

Signal to Noise Ratio (SNR): In multiplicative coherent images it figure out the suppression in the noise mainly in coherent imaging.

Mean Square Error (MSE): It computes the accuracy of each input in the sample recovers with the channel output. It is highly dependent on scaling intensity of the image.

Mean Absolute Error (MAE): It finds the mean of Absolute errors. The absolute error is the absolute value of the difference between the forecasted value and the actual value.

By evaluating all the above mentioned parameters we are going to find stones present in kidneys.

5. Results

The first step involves noise removal with the help of different filtering techniques such as median filter and contrast intensification of image through image pre-processing.

Fig. 3. Original image

Fig. 4. Image after median filter and intensity adjustment

Segmentation refers to region of interest (ROI). The region where the stone is present is detected. The image after applying segmentation is as follows.

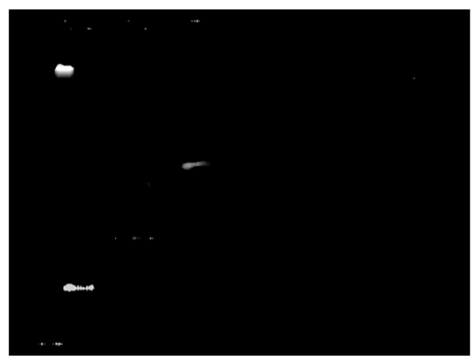

Fig. 5. Segmented Image

Morphological analysis involves the dilation/erosion of the segmented image. This step helps in differentiating the ROI from the rest of the image using different pixel values. The final image after applying morphological techniques is given in below figure.

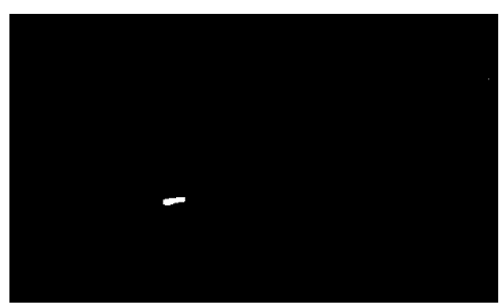

Fig. 6. Final image

Figure 7, represents the edge of the stone using edge detection method.

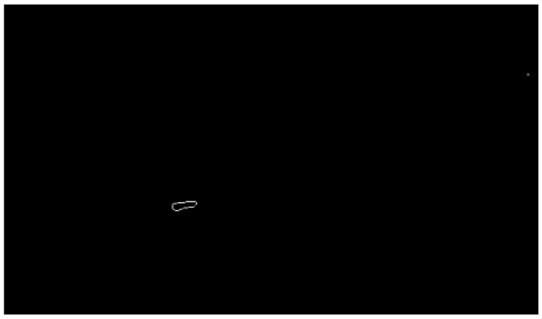

Fig. 7. Edge detection of stone

On implementing the proposed algorithm there were some variations in the exact position of the stone which could be rectified by varying the intensity adjustment of each ultrasound image of the stone. The proposed algorithm leading to an accuracy in detecting stone was 92.57%.

Figure 6, depicts the size of the stone whereas, figure 7 depicts the shape of the stone. With the help of present algorithm doctors can look forward for appropriate treatment method which can result in the removal of stone from kidneys in an efficient manner.

6. Conclusion

The proposed methodology of detecting the presence of stones formed in kidneys has been done by pre-processing the ultrasound image followed by its segmentation and finally performing morphological analysis on the resulting image. The resulting image helped in detecting the exact location of stone and further the edge detection method was used to identify the shape and structure of the stones formed. The strategic combination of these three methods proved to be an accurate method that can be used in the process of detection of kidney stone. The accuracy of proposed algorithm is 92.57% which is competent enough as compared to previous algorithms.

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