International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Detection of Kidney Stones Using Image Processing

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ABSTRACT

A kidney stone (renal calculi) disease is a common disorder worldwide with an obvious increase in incidence over the past 20 years. Every year, millions of people visit health care providers and emergency rooms for kidney stone-related complications. The causes for the kidney stone includes food habits, family history of kidney stones, metabolic disorder, high level of calcium and uric acid metabolism. The main reason for kidney stone is the formation of physiochemical substances in the urinary system. The highly concentrated urine with salts is the main cause of the stone. These salts become supersaturated precipitate and form into crystals. The crystals can either excreted or grow into stone due to the stone-promoting or stone inhibiting agents. Kidney stones are caused by various organic and inorganic substances such as calcareous, uric acid, cysteine, struvite and ammonium acid combined with proteins. Among this, 80% of stones are composed of calcium compounds such as calcium oxalate and calcium phosphate. Sometimes the metabolic changes, hyperparathyroidism, distal renal tubular acidosis, malabsorptive syndrome, obesity and diabetes severity can also cause the kidney stone formation.

Kidney stones are deposits of solid crystals, minerals, and acid salts that stick together in the urine. They are often called as renal calculi. Current estimation is that there are half a million people suffering by this disease every year. They can block the flow of urine and cause infection, kidney damage or even failure. During surgical processes, it is vital to recognize the accurate and precise location of kidney stone. The detection of kidney stones using ultrasound imaging is a rigorous task as they have low contrast and contain speckle noise. This challenge is overcome by employing suitable filter processing techniques. However, to detect the kidney stones, median filters is used to improve the rate of high accuracy and sensitivity in comparison with Gabor and Mean filter. The Fuzzy C-Mean (FCM) clustering algorithm is used here is to segment computed tomography images to detect kidney stones in their very early stages. These filters are used to improve the detection rate in terms of accuracy and sensitivity.

Keywords: Kidney stone analysis, Median filter, Gabor filter, Mean filter, Noise filtering Techniques using Matlab, Fuzzy C-Mean (FCM), Speckle noise removal, Ultrasound denoising.

I. INTRODUCTION

A Human body is made of 10 organs namely Brain, Eyes, Ears, Heart, Lungs, Lever, Intestine, Spleen, Re-productive organs and Kidney. To explain the whole body's working functions, total 8 systems are introduced in medical field like Central nerves system, Peripheral nerves system, cardiovascular system, Respiratory system, Gastrointestinal system, Muscular-skeleton system, Hematological system and Genitor Urinary system. Kidney is an important part of a human body. In a human body, Kidney performs many functions like excretion, maintaining acid-base balance, maintaining electrolyte balance, involved in maintenance of blood pressure and metabolism, synthesis of vitamin D in course of performing its regular function. It is exposed to many metabolized of human body. In the background of infection genetic pre-disposition, medication state of illness, kidney stones may be developed.

Urolithiasis is known as stone formation in the urinary system including kidney and bladder. Nephrolithiasis word comes from Ancient Greek word "nephros" means kidney and "lithiasis" means stone related to the presence of calculi in the kidneys. A Calyceal calculus refers to aggregation in either the minor or major calyx, parts of the kidney that pass urine in to the ureter (the tube connecting the kidneys to the urinary bladder). This condition is called ureterolithiasis when a calculus is located in the ureter. Signs and symptoms of having Kidney Stones .

1. Abdominal pain
2. Nausea
3. Vomiting
4. Fever
5. Blood in the urine
6. Pus in the urine
7. Painful urination, etc.

The pain arise due to kidney stone is usually beginning in the flank or lower back and often radiating to the groin or genitals. This kind of pain is also known as renal colic. The pain often comes in waves lasting 20 to 60 minutes.

The investigation of kidney stones plays a vital role in the management of kidney stone affected patients. Many medical imaging modalities are available for the diagnosis of stone. The abdominal X-ray imaging, Intravenous Urogram (IVU), Ultrasound Imaging, Computed Tomography (CT), and Magnetic Resonance Imaging (MRI) are some of the prevailing imaging technique for the management of kidney stone patients. Plain X-ray is a familiar imaging technique for the diagnosis of moderate size and radio-opaque kidney stones with less radiation. It has the limitation of reflecting radiolucent and small size stones.

IVU is the imaging method useful for determining and confirming the kidney stone. It is the useful preliminary planning of treatment and provides anatomical details of stone effectively. The radiation dose is lower in IVU, and the anatomic attributes are better than the axial CT. However, it is time-consuming, produces an allergic reaction, metabolic disturbances due to high radiation when compared to ultrasound or MRI.

CT is popular for kidney stone diagnosis without using a contrast agent. It is very useful for small and radiolucent stones detection. The use of CT in kidney stone detection provides maximized diagnostic information as it can provide the exact location of the stone. However, repeated use of CT for kidney stone examination contributes to increased exposure to radiation.

The cost of CT is high when compared to X-ray or ultrasound scan. MRI has limitations in the diagnosis of kidney stone than CT. However, it has the merit of less time consumption and nil ionization. It requires no intravenous contrast media as a collective system. But, the stones are visualized as signal and cannot be distinguished from a blood clot and tumor. Ultrasound is the most popularly used medical imaging technique for kidney stone detection. It has no radiation exposure or any other side effects. It is quick, inexpensive and detects maximum kidney stones. It can locate both radiopaque and radiolucent stones. The limitations are the echoes caused by renal fats and an intrarenal vessel sometimes mimics small stones. The echoes source the artifact to the scanned images is called as speckle. The speckle makes the ultrasound inefficient in detecting the small stones.

Image processing is a very effective way to properly detect the stone. Imaging is the most important component in the medical field. A clinician can examine the internal organs using medical imaging. CT scans, Ultrasound scans, and Doppler scans all have different scanning methods. Nowadays, the automated technique is being employed in the medical industry to analyze diseases. Many frequent issues may arise due to the diagnosis by automation, such as the use of inaccurate results, inadequate algorithms, etc. Generally, the process of medical diagnosis is very complex and hazy.

Additionally, several mathematical approaches were previously utilized to identify kidney stones using ultrasound images. Among all the approaches for detecting kidney stones, image processing has the most advantages since it analyses the stone with great precision. Ultrasound imaging is one of the current noninvasive, low-cost, and commonly utilized imaging modalities for assessing renal disorders.

II. METHODS AND MATERIAL

This section provides a detailed overview of various existing kidney stone detection techniques using various images. Identifying kidney stones in the human body is a tedious task as it can be life-threatening if misdiagnosed. So on the way to do away with or lessen misguided detection of kidney stones most of the researchers have given their contribution through offering green 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.

In 2012, Sadeghi et al. looked at the radiographic method, which employs an X-beam to hunt for stones more quickly and precisely. It demonstrates that most urethral stones are dull and cloudy. The barrier is that exact and precise recognition is limited in this manner. In 2013, Rahman and Uddin created and implemented a system for segmenting the human kidney from ultrasound pictures, which can be used during surgical procedures such as punctures. After restoring an input picture, use the Gabor filter to minimize speckle noise and smooth the output image. Histogram equalization is used to improve the image quality [10]. By lowering specific vitality levels that confirm the presence of urinary calculus in a specific area, Viswanath and Gunasundari improved accuracy in 2014. To complete the procedure, the artificial neural network idea was effectively applied [11].

According to the article [12], authors have proposed a novel method for detecting the kidney stones. According to this report, ultrasound is far superior to computed tomography. In 2015, Viswanath and Gunasundari again an improved kidney stone detection procedure. To reduce speckle noise, the ultrasound picture is pre-processed and recovered. The reconstructed image is smoothed using a Gabor filter before being improved with histogram equalization. The stone area is detected using double-level set segmentation [13]. The three-dimensional kidney model created by Mallala et al. was created using a c-arm tomographic imaging approach. Their findings demonstrated that c-arm tomography images of the kidney might yield matrices for the diagnosis of kidney stones. Unfortunately, evaluated tomography images of the kidney increase susceptibility to more radioactivity compare to traditional X-ray imaging, particularly in patients seeking frequent monitoring and youngsters with fewer bones [14].

In order to detect the kidney stones, the work [15] has applied a level set-based segmentation approach. In this approach, the input image is pre-processed and the region of interest is partitioned. In [16], the authors explored kidney stones in the human body and shown the way to identify them using image processing techniques. The technique uses pre-processing segmentation and morphological analysis. In [17], the authors have presented an image processing technique for detecting kidney stones without the use of humans. Segmentation and morphological studies were carried out for the technique. The authors in [18] proposed a novel technique using Gabor transform to detect the edges in the computerized tomography (CT) and magnetic resonance image (MRI) images. The technique is very useful to detect the kidney stones as well.

In [19], the authors introduced an automated kidney detection technique using 3-dimensional ultrasound image. This technique mainly determines the shape of the kidney. The scheme can also be used to detect the kidney stone. The work [20] mainly pointed out several image processing based methodology to detect stones in Gall Bladder. Work [21] proposed an improved scheme for detecting kidney stones using ultrasound images. The scheme has used an improved image segmentation method in order to increase the accuracy. In order to predict and estimate the quality of the image, the authors of [22] suggested a methodology of extracting some local features of image. The work can show the future direction for detecting the kidney stones more accurately. In [23], authors examined an advanced scheme to detect the proper location of the stone. The work is divided in to several sub-phases such as pre-processing, segmentation, detection, and classification.

The authors of [2] have proposed an efficient image classification method called ExDark19. The scheme has used transfer to detect kidney stones from CT images. The iterative neighbourhood component analysis (INCA) is incorporated to choose the most informative & significant feature vectors and then selected vectors are classified using k nearest neighbour (kNN) classifier with a ten-fold cross-validation technique to detect the stones. In order to reduce the inaccuracy in detecting stone, the authors of have proposed back propagation network (BPN). The BPN can reduce the noise and detect classify the kidney stone properly. The work has used bilateral filter, Adaptive Histogram Equalization, and watershed algorithm for the purpose of removing the noise, enhancing the image contrast, and image segmentation respectively to detect the kidney stone efficiently

Mallala et al. investigated the technique of C-arm tomography in their work to develop the three-dimensional structure of the 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. 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. In addition, uric acid stones were not observed and smaller stones were out of the view. Hence, kidney stone detection is done in an improved method by using Doppler imaging sequence by Cunitz et al. This paper also quoted that ultrasound is better than computed Tomography (C.T).

Sun et al. designed a rotating sonoprobe capable of acquiring sonographic images from four identical angles with respect to a fixed and rotating axis. Manual estimation of kidney volume is time consuming and unreliable. Their method is performed so we can minimizet the energy functions. Therefore, their automated method for kidney stone calculation is more accurate and precise than the manual method. This three-dimensional analysis was developed by Marsusi et al. to improve detection of kidney stones by automatic methods. Their method automatically diagnoses and segments kidneys in "abdominal ultrasound images". works by Cao et al. shows that determining the exact location of kidney stones is very important for extracorporeal shock wave lithotripsy (ESWL). Because shock waves are used to focus on kidney stones in real time, failure of the shock wave can cause injury or tissue damage. His research shows that ultrasound images contain speckle noise that needs to be removed. Rahman and others. The proposed speckle noise reduction and segmentation of renal ultrasound images not only improves kidney stone detection but also improves image quality. So, Vishwanath et al. [15] extracted some energy levels that indicate the presence of kidney stones at a given location, and their work then applied multi-layer perception (MP) and back propagation (BP) to increase the accuracy of the detected stone type to 98.9%.

Methodology:

The first step is to collect the ultrasound images and organize a dataset. After dataset collection, the next step follows, Image pre-processing, Image Segmentation, and Morphological Analysis.

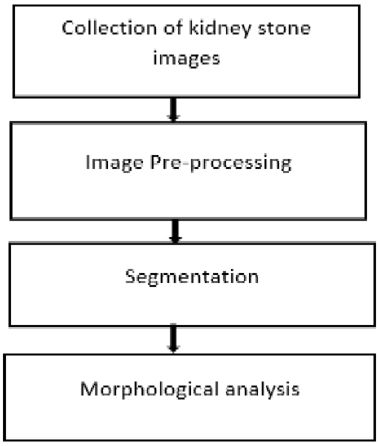

Figure 1: Block Diagram

1. Image pre-processing

The purpose of pre-processing is to improve image data, remove unwanted distortions and improve some image features. Noise reduction through a filter operation helps to increase or decrease certain image details and makes image evaluation easier and faster. It involves specific filtering, Image enhancement, edge filtering. Ultrasound images consists of a lot of fleck noises. The presence of the noise disturbs the ultrasonic image. Owing to this disturbance we can get inaccurate detection of the stone which causes damages in the time of 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.

2. Image Segmentation

Image segmentation is the process of dividing a digital image into sets of pixels which are also known as super pixels. The ROI model is usually used to identify the abnormal region based on clusters and centroids.

Figure 2: Kidney Stone Image Segmentation

Present step involves clustering algorithm, which categorize the input data points into different categories depending on their inherent distance from each other. The main task is to remove the distortion in the source image. It removes the undesired noise and enhances the features of the image. The images are preprocessed using DWT. Image enhancement is done because of removing noise and brighten the image. Wavelets are designed to transform an input image into a sequence of wavelets that can be processed more efficiently than pixel blocks. The entire image is converted into high and low pass filters. Image is divided into 4 sub bands like Low-Low, Low-High, High-High, High-Low. The LL sub band is considered as both horizontal and vertical version of image. The other three subgroups LH, HH, HL are groups with higher frequency data.

3. Morphological Analysis

Morphing is the process of transforming object shapes from one form to other. Morphological operations are used to smooth the field of interest. At the time of morphological operations process the images depends on the shape. During processing, it removes unwanted data called pixels from the outer region of the region of interest. It includes dilution and erosion.

4. Back Propagation Neural Network

The technique used in artificial neural network back propagation is gradient descent to compute a gradient needed in the calculation of weights to use. It is a group of I/O connections where each connection has its own weight associated with the programs. The artificial neural networks built on human nervous system It trains neural networks using the back propagation algorithm. This technique is known as delta rule or gradient descent, the algorithm searches for the lowest value of the error function. It can be used to solve problems including classification and regression. The algorithm's main goal is to reduce errors by changing their weights.

5. Fuzzy C Means Algorithm

Clustering is the process of grouping large amounts of data into smaller amount of related data. Fuzzy clustering is an unsupervised clustering technique that determines clustering parameters without the intervention of a human. Based on distance metrics between the data point and the cluster center, every piece of data belonging to every centroid is given a threshold value. It's seen a lot in pattern recognition. This algorithm allows data points to belong to several clusters. This separates large sets of data into smaller and similar ones. Unlike k-means clustering, fuzzy-c means clustering fits well with overlapped data sets, allowing us to pinpoint the exact location of the kidney stone.

Figure 3: Ultrasound image of kidney

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 determines the loss and compression loss after recovery. 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 fully dependent on the scaling intensity of an image. Mean Absolute Error (MAE): It finds the mean of Absolute errors. Absolute error is the absolute value of the difference between the predicted value and the actual value. By evaluating all the parameters mentioned above, we find stones in the kidneys.

Fuzzy C Means Algorithm

Convolution is a neighborhood operation where each output pixel. is the total sum weighted to neighboring input pixels. The main disadvantage of convolutional filters is that they are not suitable for all types of sound. It is sensitive to deviations in direction and magnitude. Median filter and rank filter are used to detect kidney stones in ultrasound images. These also have some disadvantages. A median filter removes both noise and fine detail because it cannot tell the difference between the two. Anything relatively small compared to the size of the neighborhood will have a minimal effect on the median value and will be filtered out. The median filter will not distinguish fine detail from noise.

Clustering is the process of grouping large amounts of data into small clusters of related data. Fuzzy clustering is an unsupervised clustering technique that determines clustering parameters without the intervention of a human. Based on distance metrics between the data point and the cluster center, every piece of data belonging to every centroid is given a threshold value. It's seen a lot in pattern recognition. This algorithm allows data points to belong to several clusters. It separates large sets of data into smaller, similar groups of data. Unlike k-means clustering, fuzzy-c means clustering fits well with overlapped data sets, allowing us to pinpoint the exact location of the kidney stone. Fuzzy C-Means (FCM) algorithm is often used for unsupervised image segmentation. However, the FCM algorithm does not consider location information in the context of the image.

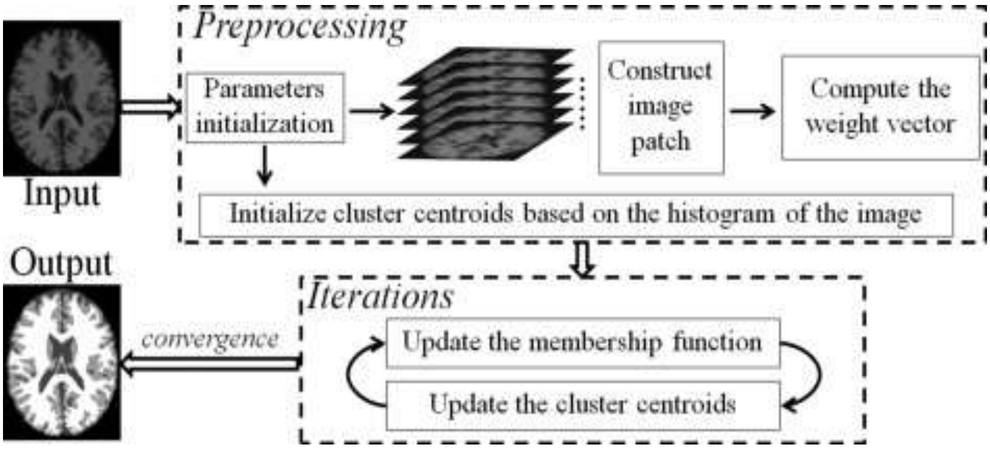

Figure 4: Fuzzy C-Means Algorithm

This makes the FCM algorithm sensitive to additional noise that degrades the pixel characteristics of the image. An approach to integrate local context data and member information is presented in FCM. The approach is to add a weighted regularization function to the standard FCM algorithm. This function is designed to be similar to the standard FCM objective function, but the distance is replaced by a new interval generated from local addition or residual membership. The adjustment weight used is a constant weight or alternatively an adaptive weight. The adaptive weight is the Euclidean distance between the prototype mean and the mean of the local image. The normalization function aims to smooth out the excess noise and affect the clustering image into homogeneous regions. Simulation results of clustering and segmentation of synthetic and real noisy images were presented.

Algorithm 1 Fuzzy C-Means Algorithm

1: Initialize U=[u_{ij}] matrix, $U^{(0)}$

2: At k-step: calculate the center vectors $C^{(k)}$ = [c_j] with $U^{(k)}$

3: $C_i = \frac{\sum_{j=1}^{n} u_{ij}^{m} x_j}{\sum_{j=1}^{n} u_{ij}^{m}}$

4: Update U(k), U(k+1)

5: $u_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|} \right)^{\frac{2}{m-1}}}$

6: If $\|U^{(k+1)} - U^{(k)}\| < \varepsilon$ then STOP;

7: Else

8: return to step 2.

As one form of photo segmentation algorithms, fuzzy C-way clustering is an powerful and concise segmentation set of rules. However, the downside of FCM is that it's far touchy to photo noise. To resolve the problem, to designs a unique fuzzy C-suggest clustering set of rules primarily based totally on multi-goal optimization. To upload a parameter λ to the bushy distance size formulation to enhance the multi-goal optimization. The parameter λ can alter the weights of the pixel neighborhood information. In the set of rules, the neighborhood correlation of neighboring pixels is delivered to the progressed multi-goal mathematical version to optimize the clustering cent.

III. RESULTS AND DISCUSSION

Experiments are performed using MATLAB. Pictures of kidney stones are considered an entry. In this study, the algorithm used is a median filter to remove noise in the ultrasound image and detect kidney stone in the ultrasound image, but compared to the other algorithm, the median filter gives better results. Image resolution can be further improved with advanced filters. Two different experimental results show that the new fuzzy c-means approach has better performance and computational time when images are segmented by different types of noise.

Analysis – Accuracy and Sensitivity

S.NO	**Median filter**		**Rank filter**	
Parameter	**Accuracy**	**Sensitivity**	**Accuracy**	**Sensitivity**
1.	85.6	84.2	81.5	80.1
2.	89.5	88.2	82.3	81.2
3.	86.2	83.2	82.9	81.3
4.	87.2	84.2	84.1	83.6
5.	86.3	82.3	82.3	84.3
6.	91.3	85.2	85.3	82.3
7.	89.2	86.1	84.2	82.3
8.	91.5	88.5	86.2	84.3
9.	89.3	84.3	84.1	82.3
10.	88.5	86.2	82.3	80.6
11.	84.3	80.3	80.3	80.1
12.	87.2	84.2	84.2	81.3
13.	89.3	85.2	86.2	82.3
14.	84.2	81.3	81.6	80.4
15.	89.4	85.2	85.6	81.3
16.	88.9	84.1	84.2	82.3
17.	87.3	83.1	86.2	84.6
18.	90.6	84.3	84.2	81.2

The median filter has a better accuracy than the 4.24% rank filter and also the median filter has a higher sensitivity than the 5.25% rank filter. Therefore, median filters have significant performance compared to rank filters. A pre-test analysis was performed with a p-value of 0.8 (g-power 80%). Image processing has become a common method of creating images that are more understandable to the human eye. Those captured images sometimes corrupted by the noises.

There are many methods for removing impulse noise in grayscale and color images. But very little has been done to remove noise in color images. Of the many filters offered, most are only for grayscale images. Image filtering techniques can generally be classified as linear and non-linear. Linear filters can be used to remove specific types of noise.

A linear filter is a filter where the value of the output pixels is a linear combination of the values of the pixels in the vicinity of the input pixels. A linear filter is a filter where the value of the output pixel is a linear combination of the values of the pixels in the vicinity of the input pixel.

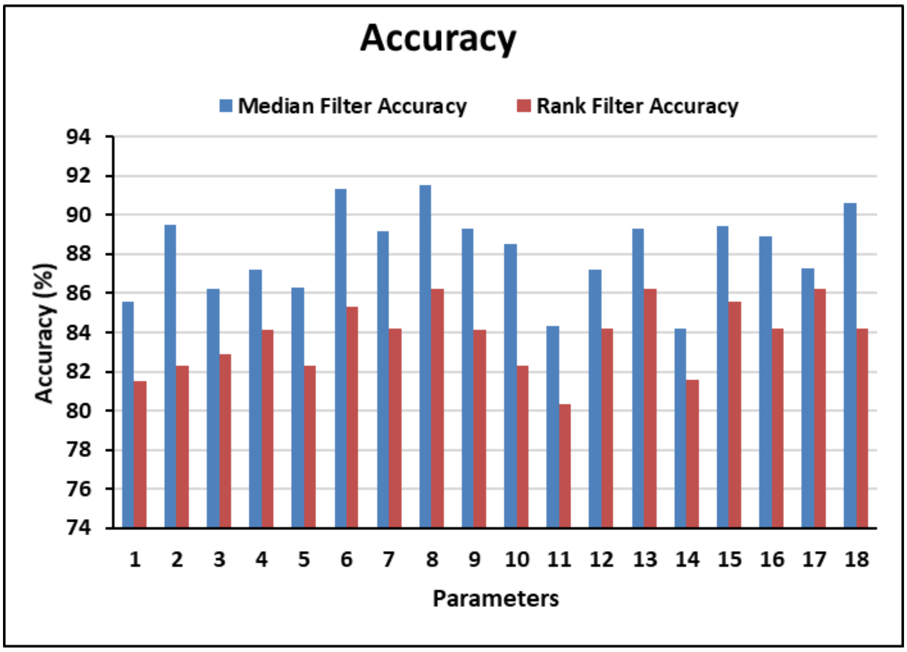

Figure 5: Accuracy Graph

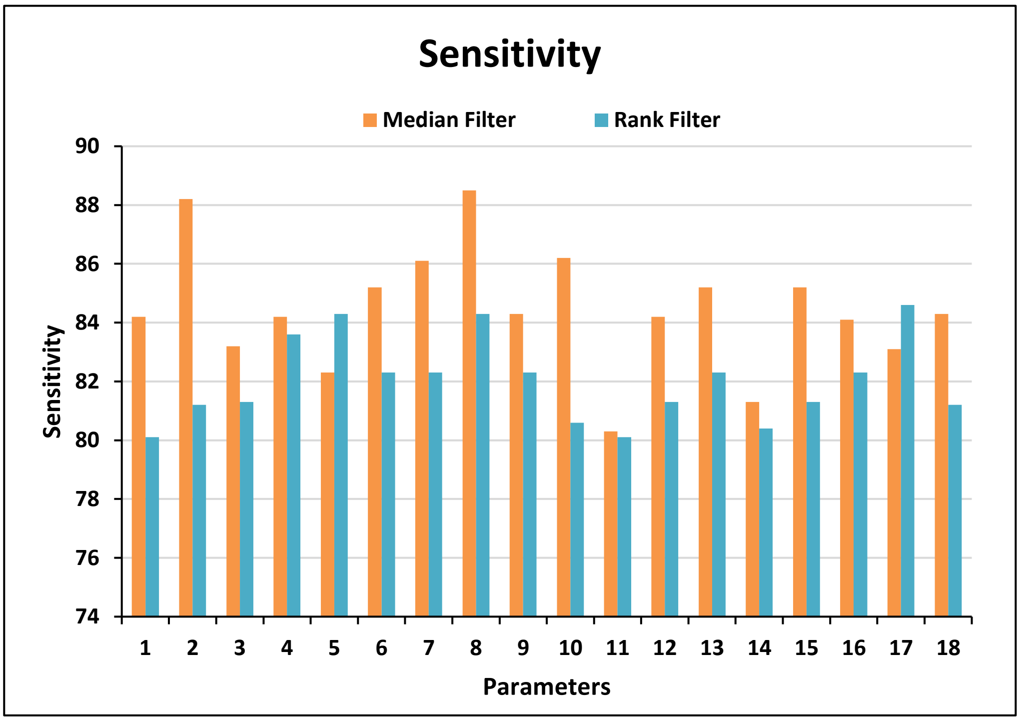

Figure 6: Sensitivity Graph

Using the MATLAB simulation tool, the following results were obtained and it was found that the median filters gave significant results compared to the rank filters. First, it removes the noise and detects the rock with an interval filter. In this study, IBM SPSS software analysis was done for the project. The mean precision and sensitivity were analyzed by repeating 20 samples and group statistics and independent sample tests, and the results were analyzed by SPSS and the charts obtained.

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 95.7% which is competent enough as compared to previous algorithms. Based on the results and tabulations, the detection rate of the kidney stones in ultrasound images using median filters has improved in terms of accuracy and sensitivity compared with the accuracy and Sensitivity of rank filter. So, we proved that the median filter is more accurate than other filters.

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