

Detection of Kidney Stones in Ultrasound Images Using Median Filter Compared with Rank Filter

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Abstract

Aim: To detect the kidney stones in ultrasound images using median filters to improve the detection rate in terms of accuracy and sensitivity. **Materials and Methods:** The accuracy and sensitivity of median filter ($n=114$) was compared with rank filter ($n=114$). The median filter is used to detect the kidney stone in ultrasound images. 114 is the sample size taken with the p -value 0.8 and has been used to improve detection rate of kidney stones in terms of accuracy and sensitivity using Matlab simulation tool. **Results:** According to the results obtained Median filter has accuracy (86.4%) and rank filter has accuracy (82.2%) and also sensitivity of median filter (87.7%) and sensitivity of rank filter is (82.5%). Median filter has a significantly higher accuracy ($p=0.018$) and sensitivity ($p<0.01$) compared with the rank filter. **Conclusion:** The detection rate is improved using the Median filter compared with rank filter in terms of accuracy and sensitivity.

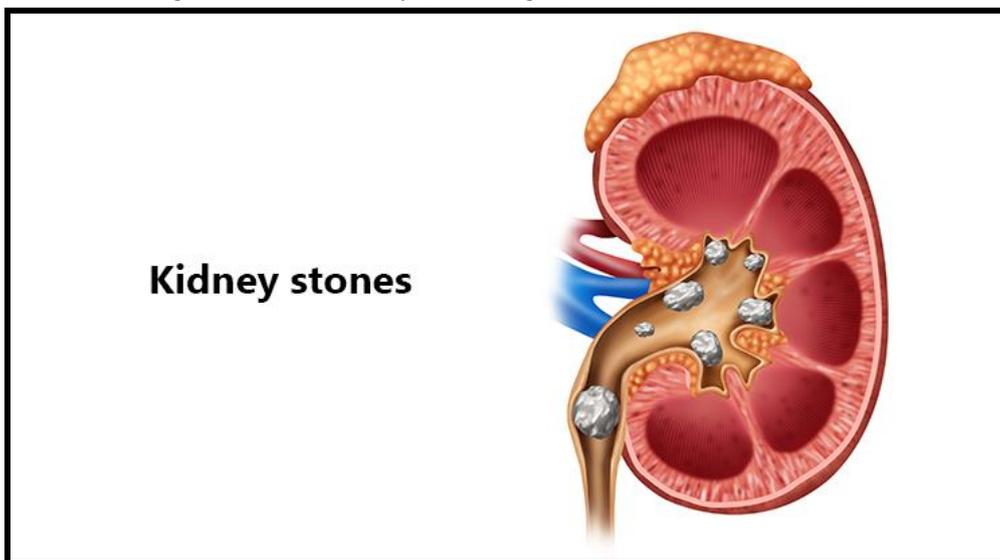
Key-words: Image Processing, Rank Filter, Innovative Median Filter.

1. Introduction

Ultrasound imaging is one of the imaging techniques used for diagnosis of kidney abnormalities. The kidney abnormalities such as formation of stones as shown in **Fig. 1** (Akkasaligar, Biradar, and Kumbar 2017). During surgery it is very hard to recognize the precise location of the kidney stone. Kidney stone disease is one of the most life threatening diseases in the world wide. The main function of the kidney is to regulate the balance of electrolytes in the blood. Kidney is a bean

shaped organ and present on each side of the spine (Akkasaligar and Biradar 2016). The main application of detection is used in brain tumor detection and thyroid segmentation. The applications of image processing are used in Image sharpening and restoration, Medical field, Color Processing, Pattern Recognition. The disadvantage of ultrasound images is that they have low contrast and speckle noise. It is a challenging task for detection of kidney stones. Speckle noise is an inherent property of medical ultrasound imaging, and it generally tends to reduce the image resolution and contrast, thereby reducing the diagnostic value of the imaging modality (Karthick 2019). The proposed algorithm is median filter, it works by moving through the image pixel by pixel replacing each value with the median values of neighboring pixels. It is particularly effective at removing noise while preserving edges. The median filter is calculated by initial sorting all the picture element prices from the window in numerical order then exchanging the picture. Ultrasound imaging is a process in which high frequency sound waves are used to monitor or to capture the internal organs in the body. Through this technique we can find the damaged parts inside the body. Hence ultrasound imaging is used to detect the stones in the kidney (Raja et al. 2007).

Fig. 1 - Stones in kidney (Akkasaligar, Biradar, and Kumbar 2017)



In the last 5 years there were 16000 articles in google scholar and IEEE xplore on kidney stone detection using different types of filters. Digital image processing is used to find the images which have low contrast and speckle noise.(Ranjitha 2019) . Speckle noise and shadows present in ultrasound images makes the identification of kidney stones very complex(Rahman and Uddin 2013). ANN based classification reduces diagnosis time and increases the efficiency with accuracy(Ebrahimi

et al. 2015). The preprocessed image is formed with level set segmentation to detect the stone region. (Rathi, Gladis Pushpa, and Palani 2011). Based on the overall analysis, detection of kidney stones in ultrasound images using ANN classification has better to detect the stone in the kidney.(Viswanath and Gunasundari 2016).

Previously our team has a rich experience in working on various research projects across multiple disciplines (Sathish and Karthick 2020; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020). Now the growing trend in this area motivated us to pursue this project.

The detection of kidney stones is a highly challenging task as they have low contrast and speckle noise. This challenge is overcome by using suitable imaging techniques and filters. Ultrasound images normally consist of speckle noise which cannot be removed by normal filters. So the median filtering algorithm is proposed, the median filter removes the speckle noise. The preprocessed image is achieved with a median filter to remove noise and to detect the stone region. Majority of people with kidney stone disease do not notice the disease as it damages organs slowly before showing symptoms. Different types of kidney stones namely renal calculi, struvite stones, staghorn stones were analyzed.(Hafizah and Supriyanto 2011). In order to get rid of the painful disorder the kidney stone is diagnosed through ultrasound images and then removed through a surgical process like breaking up of stone into smaller pieces which then pass through the urinary tract.

2. Materials and Methods

Study setting of proposed work is done in our university. The number of groups identified for the study is 2. The group 1 is median filter and group 2 is rank filter. Matlab 2014a tool kit will be used to write the code and simulate. Using matlab accuracy and sensitivity has been calculated for the required algorithm and then results have been compared. Sample size per group is 114 (Kane, Phar, and BCPS n.d.). Median filter and rank filter are explained below. SPSS software has been used to compare the results and to find the graph. The pre-test analysis has done with p-value with 0.8 (g-power 80%).

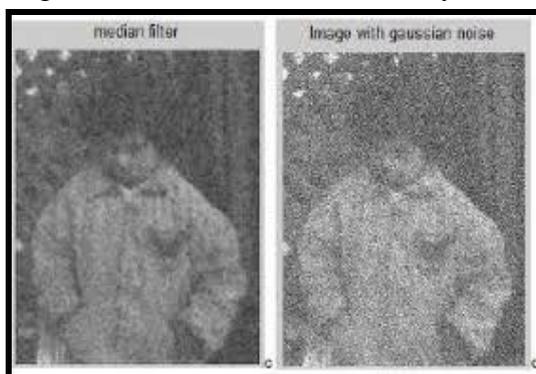
3. Median Filter

Accuracy and sensitivity of the median filter are analyzed by varying different ultrasound images in the MATLAB simulation tool. Matlab(2014a) will be used for simulation with required add-ons installed, these are predefined functions in the matlab for the image processing. Open matlab software and open new m.file. Write the code for the median filter and save the file in the desired location. Store the input images in the location using the median filter algorithm. Then extract kidney images and find the stone in the ultrasound image. After processing the code the output image will be displayed in the command window and repeat the experiment for different kidney ultrasound images and get the output and find the detection rate using the formula. Kidney stone ultrasound images are taken as input images which are independent variables. Accuracy and sensitivity will be as output variables. By comparing the results a better algorithm has been decided. Detection rate of the algorithms will be calculated using the formula.

$$\text{Detection rate} = (\text{No. of output images}/\text{Total input images}) * 100$$

The Median filter removes the speckle noise in an ultrasound image. Median filter is used in digital image processing to remove noise. It is an innovative method in which filtering is done using a median filter to detect stones in the kidney. Median filtering algorithm uses a neighborhood area as a filtering window, which changes the size of the filtering window according to certain setting conditions in the filtering process as shown in **Fig. 2**.

Fig. 2 - Median filter (ALhussieny 2017)



The median filter is an efficient methodology that may, to some extent, distinguish out of vary isolation from legitimate image options like edges and features. Specifically the median filter replaces a pixel by the median, instead of the average of all pixels in a neighborhood Ψ .

The median filter is a non linear signal processing technology based on statistics. The median value of the digital image will be given in the place of noisy value. The pixels of the mask are ranked in the order of the gray levels and the median of the group is stored to replace the noisy value.

$$\text{median}[A(x) + B(x)] \neq \text{median} [A(x)] + \text{median} [B(x)]$$

First start the process in the matlab tool. Collect the ultrasound images or collect different datasets of kidney images for detection of stone as shown in block diagram of **Fig. 3**. Use the median filter. The median filter removes noise in an ultrasound image using salt & pepper. So that it can detect the stone. Next step is image processing. The image processing does the improvement of the image data that suppresses unwilling distortions or enhances some image features. So finally the morphing is used for edge detection of the image.

Fig. 3 - Block Diagram of Kidney Stone Detection



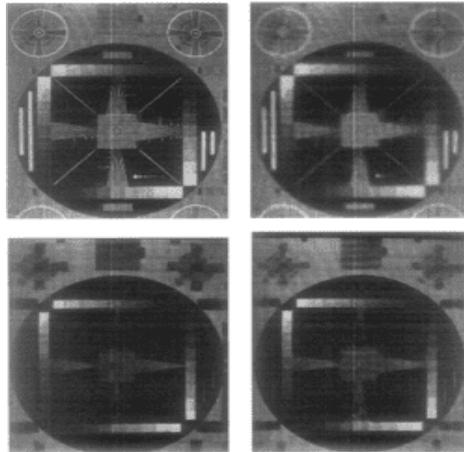
4. Rank Filter

Accuracy and sensitivity of the rank filter are analyzed by varying different ultrasound images in the MATLAB simulation tool. Matlab (2014a) will be used for simulation with required add-ons installed, these are predefined functions in the matlab for the image processing. Open matlab software and open new m.file. Write the code for the rank filter and save the file in the desired location. Store the input images in the location using the rank filter algorithm. Then extract kidney images and find the stone in the ultrasound image. After processing the code the output image will be displayed in the command window and repeat the experiment for different kidney ultrasound images and get the output and find the detection rate using the formula. Kidney stone ultrasound images are taken as input images which are independent variables. Accuracy and sensitivity will be as output variables. By comparing the results a better algorithm has been decided. Detection rate of the algorithms will be calculated using the formula.

$$\text{Detection rate} = (\text{No. of output images}/\text{Total input images}) * 100$$

Rank filters are non linear filters that use the local gray level ordering to compute the filtered value as shown in **Fig. 4**. Rank filters can be used for several purposes such as image quality enhancement, image preprocessing, feature extraction and post processing.

Fig. 4 - Rank Filter (Heygster 1982)



For rank filters, the output images got maximum same as the median filter. Because both filters remove noises in an ultrasound image. Rank filters operating on images assign the k th value of the gray levels from the window consisting of M pixels arranged according to their value to the center point of the window.(Wang et al. 2012). On implementing the planned rule there have been some variations in precise position of the stone that might be corrected by variable the intensity adjustment of every ultrasound image of the stone.

The method of image filtering depends on the relationship between noise and images and the processing requirements (Malalla et al. 2015). Typically filtering methods include median filtering and rank filtering, the median filter has achieved good results in image denoising recovery. The median filter is a typical non linear filter based on sorting statistics to complete signal recovery. The basic principle is to replace the value of the digital image or the center point of the digital sequence with the median value of the neighborhood of the point. Filtering is an important step in image processing(Sadeghi et al. 2012). Filtering is an effective method to reduce noise and improve image quality. It is widely used in image processing. MATLAB is used to realize the filtering process, which effectively improves the quality and efficiency of image processing (Cunitz et al. 2014). Image with noise is taken as independent variables in this study, and based on this output images will be shown in the command window with dependent variables accuracy and sensitivity. Detection rate will be calculated with the help of output variables.

5. Results

Kidney stone detection using median filter in Matlab simulation tool and the output obtained for stone detection is shown in above figures. With the help of present algorithms doctors can look

forward to appropriate treatment methods which can result in the removal of stone from kidneys in an appropriate manner.

Table 1 shows the accuracy and sensitivity for different samples for Median filter and Rank filter algorithm. These results were obtained by simulating the images in Matlab. In this 18 results for sample images has been taken and were shown in the table. This can be useful in comparing the both algorithms.

Table 1 - Samples taken from various datasets. From the Kaggle Dataset 114 samples were taken, All the dataset contains 2 classes (with kidney stones and without kidney stones) Tabulation explains the accuracy and sensitivity of median filter and rank filter respectively

S.NO	Median filter		Rank filter	
	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

Table 2 - Group statistics: Statistical analysis of median filter and rank filter. Mean accuracy value, standard deviation and standard error mean for median filter and rank filter algorithms are obtained for 114 iterations. It is observed that the median filter algorithm performed better than the rank filter.

Group		No of samples	mean	Std. deviation	Std. mean error
Accuracy	Median	114	86.4588	2.33704	.21888
	Rank	114	82.2956	1.99661	.18700
Sensitivity	Median	114	87.7553	2.79817	.26207
	Rank	114	82.5070	1.60313	.15015

Table 2 shows the number of samples taken and mean values of accuracy and sensitivity for the 114 samples and standard deviation were obtained for 114 samples using SPSS software. In the table standard error mean for the accuracy and sensitivity of median filter and rank filter.

Table 3 - Independent Sample test for significance and standard error determination. P value is less than 0.05 considered to be statistically significant and 95% confidence intervals were calculated.

Levene's test for equality of variances		T- test for equality of means								
		F	Sig	t	df	sig(2-tailed)	Mean difference	Std. error diff	95% confidence interval of the difference	
									lower	upper
accuracy	Equal variances assumed	5.712	.018	14.461	226	<.001	4.16316	.28789	3.59587	4.73044
	Equal variances not assumed			14.461	220.621	<.001	4.16316	.28789	3.59580	4.73052
Sensitivity	Equal variances assumed	22.922	<.001	17.376	226	<.001	5.24825	.30204	4.65308	5.84341
	Equal variances not assumed			17.376	179.967	<.001	5.24825	.30204	4.65226	5.84423

Table 3 shows the mean, standard deviation and significance difference of median filter and rank filter are obtained in SPSS and these were used to find which algorithm gives significant results.

Figure 1 shows the formation of stones in the kidney and it is detected using filters.

Figure 2 shows the sample image of the median filter, the median filter removes speckle noise in the ultrasound image. Image shows comparison of original image and after removal of noise in the image.

Figure 3 shows the block diagram of kidney stone detection using median filter. First the median filter removes noises in the image and it detects the stone from the noise image using the median filter.

Figure 4 shows the sample image of the rank filter and it shows the gray scale image to filtered image.

Figure 5 shows the original image of kidney stone and it removes noise in ultrasound images using median filter.

Figure 6 shows the removal of noise using median filter, the median filter removes noise from an original image as shown in Fig. 5.

Fig. 5 - Original Image



Fig. 6 - Removal of noise using median filter

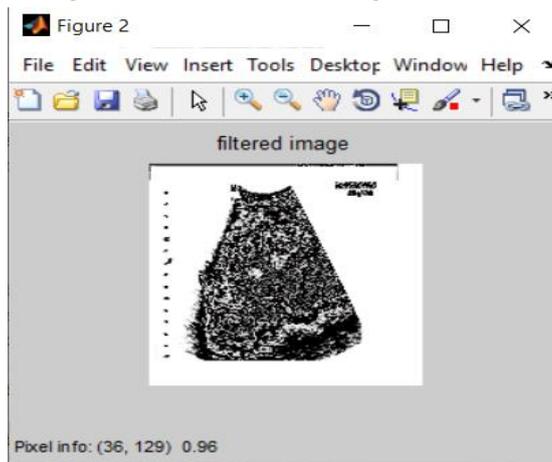


Figure 7 shows that stone is detected using median filter, so with the help of this doctor can do surgeries safely.

Fig. 7 - Stone is detected using median filter

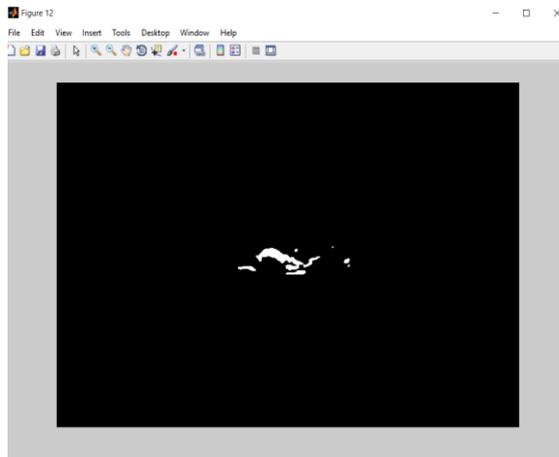


Figure 8 shows the accuracy graph which it took for 114 sample images for detection rate of kidney in terms of accuracy and sensitivity and it shows the comparison of median filter and rank filter.

Fig. 8 - Accuracy graph which shows the comparison of median filter and rank filter

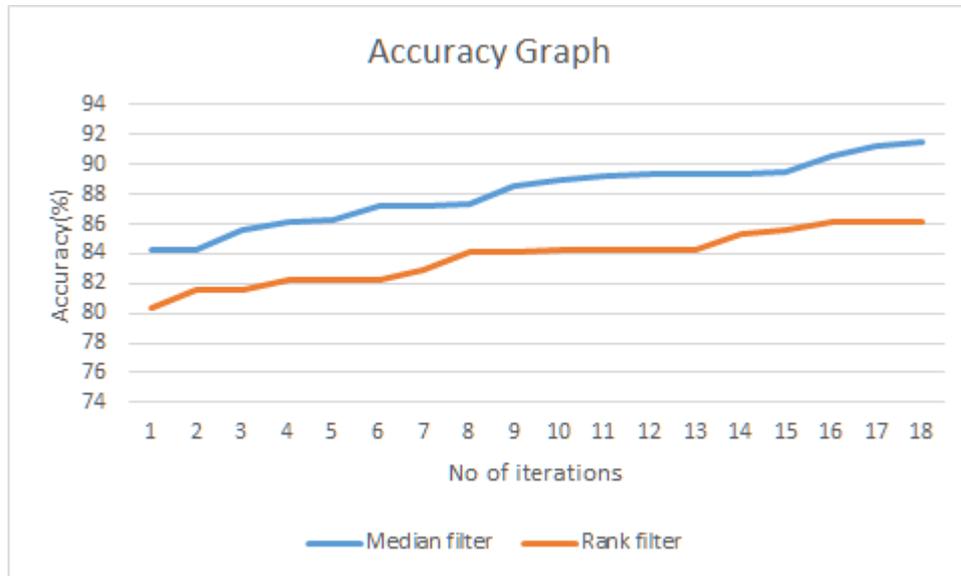


Figure 9 shows the sensitivity graph which it took for 114 sample images for detection and it shows the comparison of median filter and rank filter.

Fig. 9 - Sensitivity Graph which shows the comparison of median filter and rank filter

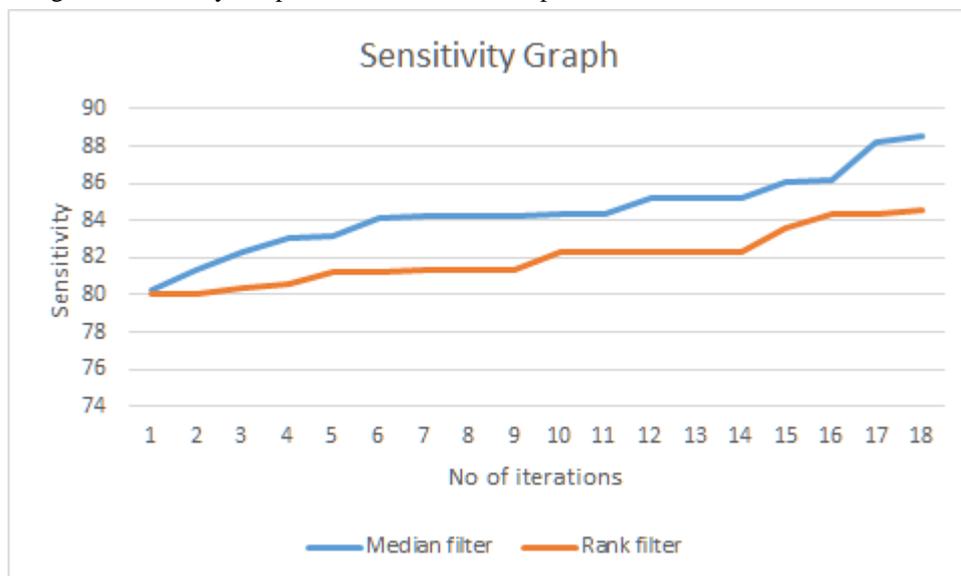
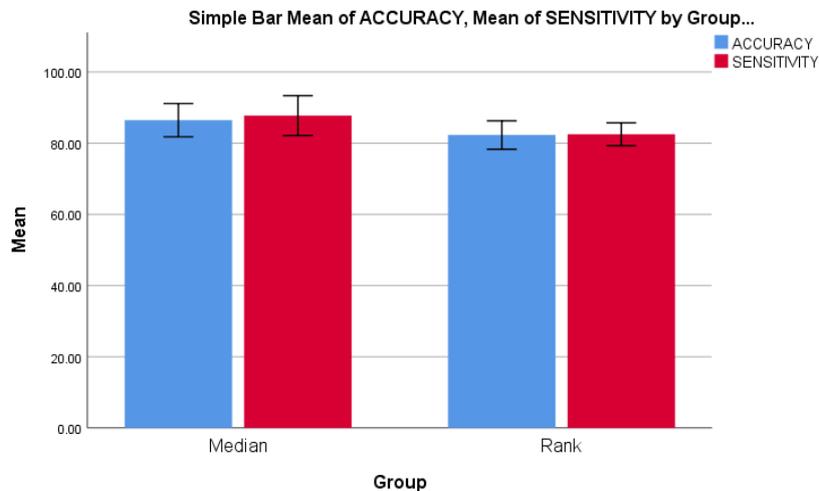


Figure 10 shows the bar chart for accuracy and sensitivity of median filter and rank filter using SPSS tool.

Fig. 10 - Graph obtained using SPSS that compares sensitivity and accuracy of median filter and rank filter. Graph obtained using SPSS that compares sensitivity and accuracy of median filter and rank filter and it shows that median filter has better Accuracy and Sensitivity compared with rank filter. In the graph median filter and rank filter are compared in x-axis and Mean of Accuracy and Sensitivity with +/- 1 SD



Using matlab tool kit simulation has done and got the results as below and have seen that median filters have given significant results compared to rank filters. First it removes noise and it will detect the stone using a median filter. In this study using IBM SPSS software analysis was done for the project. The mean accuracy and sensitivity for has analysed by iterating 20 samples and group statistics and independent sample test has done and results were analysed Using SPSS and obtained the graphs.

6. Discussion

Median filter has accuracy better than rank filter 4.24% and also median filter has sensitivity better than rank filter 5.25%. Hence median filters have significant results compared with rank filters. The pre-test analysis has done with p-value with 0.8 (g-power 80%).

Image processing has become a typical technique for creating pictures more comprehensible to the human eye. Images acquired are found to be corrupted in noise with noise in many cases. There are many methods available to remove impulse noise in gray scale and color image(Wu and Sun, n.d.). But only very little has been done for the removal of noise in color images. Of the many filters presented, most of them are only for gray scale images. Image filtering techniques may be usually

classified as linear and nonlinear(Hafizah and Supriyanto 2011). Linear filters can be used to remove certain types of noise. Linear filtering is the filtering in which the value of output pixels is a linear combination of the values of the pixels in the input pixels neighborhood (Jain 2005). Linear filtering is filtering in which the value of an output pixel is a linear combination of the values of the pixels in the input pixel's neighbourhood(Gonzalez, Woods, and Masters 2009). Convolution is a neighbourhood operation in which each output pixel. is the weighted sum of neighbouring input pixels(Hansen and Yu 2000). The main disadvantage of convolution filters is, it is not good for all types of noise. It is sensitive to variations in variations in orientation and scale.(Gonzalez, Woods, and Masters 2009; Maragos 2005).

Our institution is passionate about high quality evidence based research and has excelled in various fields (Vijayashree Priyadharsini 2019; Ezhilarasan, Apoorva, and Ashok Vardhan 2019; Ramesh et al. 2018; Mathew et al. 2020; Sridharan et al. 2019; Pc, Marimuthu, and Devadoss 2018; Ramadurai et al. 2019). We hope this study adds to this rich legacy.

Median filter and rank filter are used to find the detection of kidney stones in ultrasound images.

It also has some disadvantages. The median filter removes both noise and the fine detail since it can't tell the difference between the two. Anything relatively small in size compared to the size of the neighbourhood will have minimal effect on the value of the median, and will be filtered out. In other words, the median filter can't distinguish fine detail from noise. In this study the algorithm used is a median filter to remove noise in an ultrasound image and to detect the kidney stone in the ultrasound image, but if compared with another algorithm the median filter gets better results. Accuracy of the image can be still improved using advanced filters

7. Conclusion

Based on the results and tabulations, the detection rate of the kidney stones in ultrasound images using median filters is improved in terms of accuracy (86.4%) and sensitivity (87.7%) compared with the accuracy (82.2%) and Sensitivity (82.5%) of rank filter.

8. Declarations

Conflict of Interest

No conflict of interest in this manuscript.

Authors Contribution

Author AR was involved in image collection, analysis of image and manuscript writing. Author SP was involved in conceptualization, image validation, and critical review of manuscript.

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