Kidney Stone Detection using Image Processing Techniques on Ultrasonic Images

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***Abstract*— Renal calculi which is also called as kidney stone are crystal-based solid masses. For medical procedures, it's essential to locate the urinary calculus precisely and accurately. Since the speckle noise in ultrasound images makes it difficult to detect urinary calculi manually, it is necessary to employ automated methods to find kidney stones in ultrasound images. Ultrasound imaging is one of the imaging techniques used to identify kidney abnormalities. Changes in the structure and position of the kidneys as well as limb edema are examples of kidney abnormalities. The emergence of kidney stones, cysts, obstructed urine, congenital malformations, and malignant cells are other renal problems. This issue can be resolved by employing the appropriate image processing techniques.[1]**

Keywords—Renal calculi, Speckle noise, Kidney stone, Ultrasonic images, Image processing techniques

I. INTRODUCTION

Kidney stone formation, sometimes referred to as renal calculi, is characterised by the crystallisation of urine due to material concentration or hereditary vulnerability. Kidney stones can affect anyone, including children, although the majority of kidney stone cases go undiagnosed unless there is a severe abdominal discomfort or an irregular urine colour. Additionally, individuals with kidney stones display typical symptoms including fever, discomfort, and nausea that might be mistaken for other illnesses. It's crucial to identify kidney stones early on in order to intervene or receive the appropriate medical care.

The presence or recurrence of kidney stones affects both renal dilatation and kidney function. In terms of the severity of these disorders, it also has an impact on those who have not yet been given a diagnosis of chronic kidney disease (CKD) or chronic renal failure (CRF). But because to its asymptomatic nature, it is usually found in people undergoing a physical examination for another ailment, such as diabetes, cardiovascular disease (CVD), or any condition that predisposes to the urogenital apparatus.

Moreover, the location of urinary stones in the kidney (nephrolithiasis), ureter (ureterolithiasis), or bladder (cystolithiasis), as well as their chemical composition, are used to classify them (struvite, calcium-containing, acid, or other compounds). Figure 1 depicts urinary calculi in the human body. The stone may also be in the ureter or in the minor and major kidney calyces. Ultrasonography is used in medical imaging because it is adaptable, portable, doesn't emit ionising radiation, and is relatively inexpensive. The main drawback of ultrasound imaging is their poor quality, which results in low contrast and multiplicative speckle noise, making it difficult to detect kidney stones. The presence of speckle noise in the image reduces its quality, which has an impact on the interpretation and consequently the diagnosis given by experts.

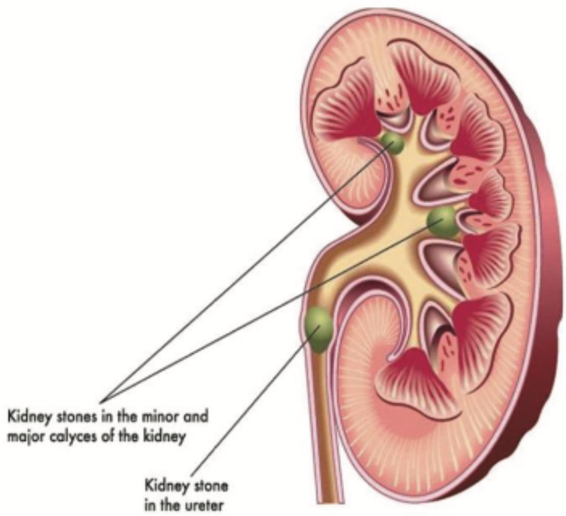

Figure 1 Location of Stone in Kidney

II. PROBLEM STATEMENT

Early detection of kidney stones is crucial since renal failure can be catastrophic. Prior to removing the kidney stone surgically, finding the stone is essential. Since the ultrasound images of the kidneys include speckle noise and low contrast, diagnosing kidney problems is a challenging task. Clinicians may find it challenging to accurately identify and detect small kidney stones as a result. To address this issue, several image processing techniques at various stages could be used to pinpoint the stone's location.

III. HOW IMAGE PROCESSING TECHNIQUES HELP IN KIDNEY STONE DETECTION?

Speckle filtering, which is required to produce an efficient stone detection system, is one of the most important and vital automated detection processes. This will make faulty detection less likely. Thanks to the varied knowledge of the judges. After pre-processing, segmentation and morphological analysis are carried out to automatically locate the stone. Numerous academics have contributed to the field of identifying urinary calculi by putting forth various methods to recognize kidney stones from MRI images. Some academics emphasize the need of producing noise-free images for segmentation. Many people concentrated on robust and efficient segmentation for the aim of precise stone recognition. After picture improvement and noise reduction, the region of interest is extracted from the ultrasound image.

IV. IMPLEMENTATION AND RESULTS

Figure-2 shows the overall block diagram of proposed method. It takes image from sample database, Image Pre-processing, Image Segmentation and Morphological analysis.

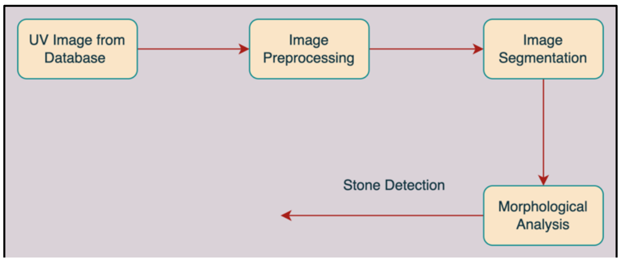

Figure 2 Block Diagram of Proposed Methodology

A. Image Pre-processing:

The ultrasound (US) image that was acquired has low contrast and is speckled with noise. As a result, the image quality might not be suitable for analysis. It's crucial to locate the kidney stone before doing any surgery. The US image requires pre-processing to address speckle noise and low contrast. Pre-processing of the US image is shown in Figure 3 and involves the following steps:

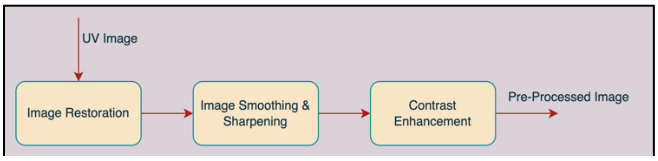

Figure 3 Image Pre-processing Steps

MATLAB Results for Image Pre-processing:

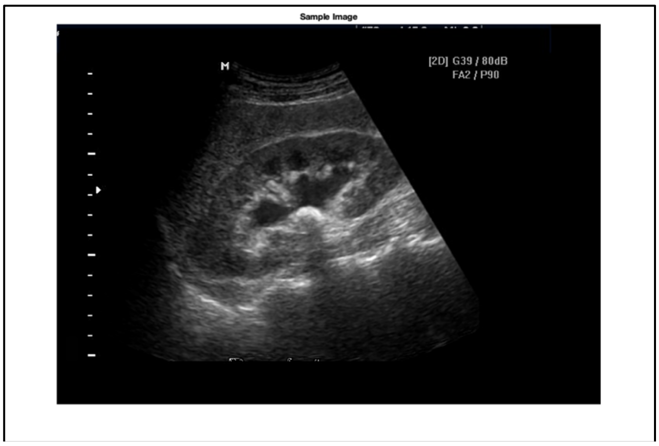

Figure 4 Sample UV Image

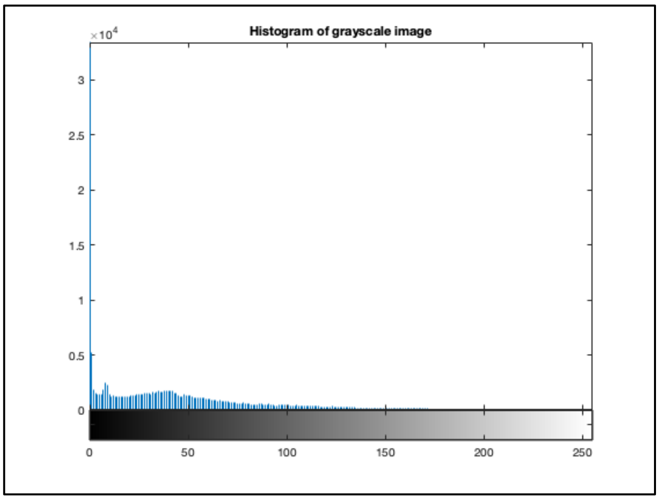

Figure 5 Histogram to find thresholding value

MATLAB CODE

```
%% Thresolding using 20 intensity value, above 20 pixel value 1 or 0

binary_image=imbinarize(gray_image,20/255);
%Binary image or c = b>20;
figure;
imshow(binary_image),title('Binary Thresolding Image');
```

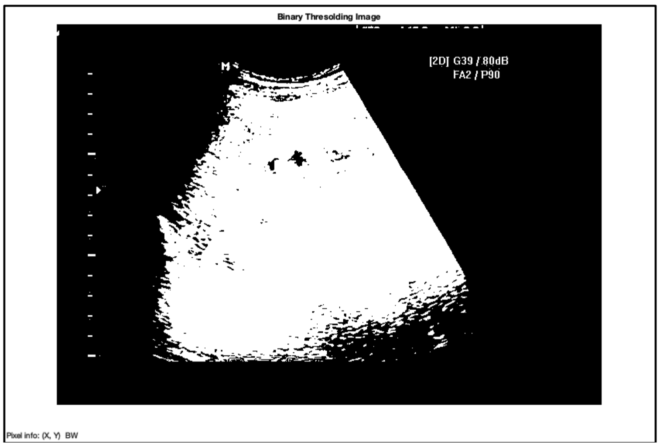

Figure 6 Binary Thresholding Image

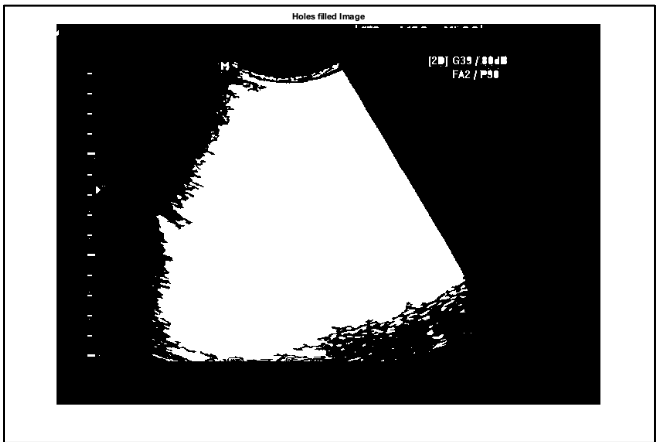

Figure 7 Holes Filled Image

```
%% Filling empty black holes in binary image(thresolding)

filled_image=imfill(binary_image,'holes');
figure;
imshow(filled_image),title('Holes filled Image');
%% Removing all binary objects which are around the Area of interest by bwareaopen function

filtered_image=bwareaopen(filled_image,1000);
%Remove small objects from binary image that have fewer than P=1000
%filtered image can be used as mask which can be apply on original image
figure;
imshow(filtered_image),title('Backgroud noise filtered Image');
%% Using filtered image as mask and multiple with original image gives complete preprocessed image

PreprocessedImage=uint8(double(original_image).*repmat(filtered_image,[1 1 3])); %for arithmetic operation
%convert into double and then again convert to uint8

figure,imshow(PreprocessedImage),title("Preprocessed Image");
```

The above MATLAB code will perform few steps of image pre-processing such as it will fill the black holes which are made after applying 20 thresholding value then using another function it will remove small binary objects that have fewer then 1000 pixels and then will make mask image.

Figure 8 Background Noise Filtered Image

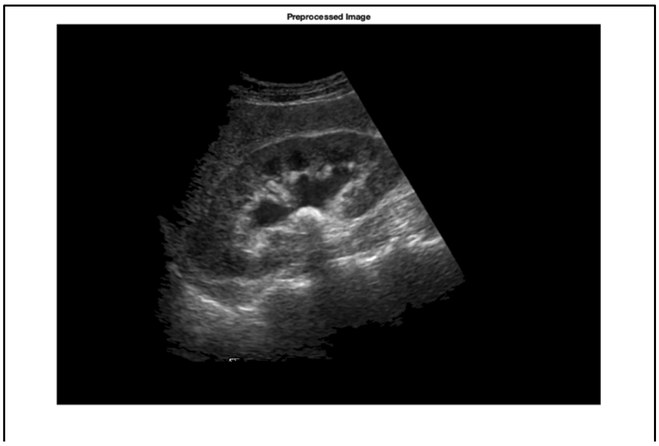

Figure 9 Pre-processed Image

```
figure,imshowpair(original_image,PreprocessedImage,'montage'),title('Original and Preprocessed Image');
%% part2 starts here

PreprocessedImage_adjust=imadjust(PreprocessedImage,[0.3 0.7],[])+50; %adjust
%imadjust function will adjust value, and <0.3 it will map to 0 & >0.7 it will map to 1 and in between [0.3,0.7] it map
```

```
% to in between floating value > this will give center area of interest and
% by adding 50 we can enhance intensity of that specific region of interest
figure;
imshow(PreprocessedImage_adjust),title("Adjusted Preprocessed Image");
```

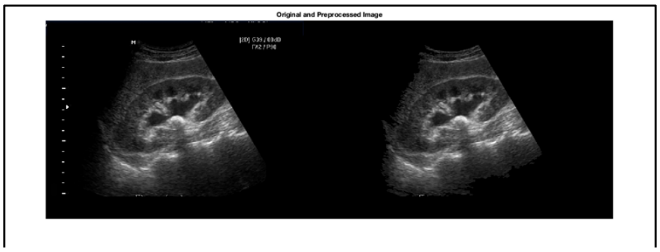

Figure 10 Original and Pre-processed Image

Figure 11 Adjusted Image

```
median_filtered_image=medfilt2(PreprocessedImage_gray,[5 5]); %median filter for noise removal or morphological analysis can be used also
figure;
imshow(median_filtered_image),title("Median Filtered Image");
impixelinfo
%imhist(median_filtered_image); %%global thresolding failed because of histogram isn't bimodel shape
```

In above MATLAB code its applying median filter for noise removal from adjusted image and median filter using 5 * 5 kernel size to implement that.

Figure 12 Median Filtered Image

B. Image Thresholding:

Image thresholding s the process of dividing a picture into sets of pixels or groups of super pixels. A ROI model is utilised to detect abnormal regions supported by clusters and centroids for efficient segmentation, according to Augustine et al. The input file points are sorted into groups according to how far apart they truly are at this moment using a clustering algorithm. It is utilised to specify the focus area or the precise spot where the majority of the required research must be done.

The traditional pixel estimates of a picture are taken into account while smoothing channels, along with fuzzy spot borders and crisp details. However, middle sifting swaps out the centre of the pixel values within a predetermined neighbourhood for the focus pixel estimation of an image. The middle pixel value is replaced with the inner pixel value when the pixel values in a specific neighbourhood are first organised during a climbing request. This eliminates background noise from photos and dulls their sting.

```
final_filtered=median_filtered_image>250;
%%applying thresolding intensity value of 250 to get main area
figure;
imshow(final_filtered),title("Final Filtered Image");
impixelinfo
```

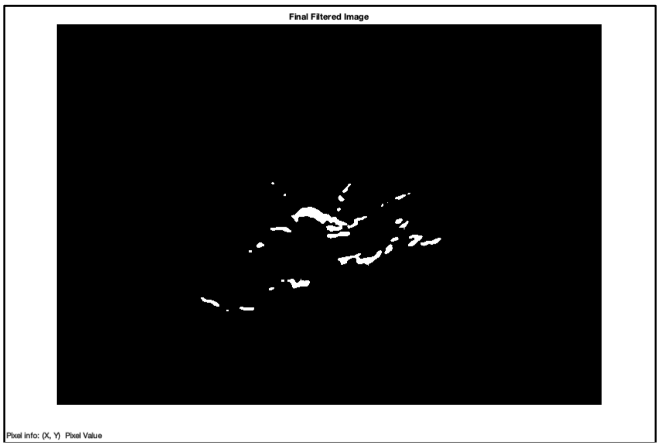

Figure 13 Final Filtered Image

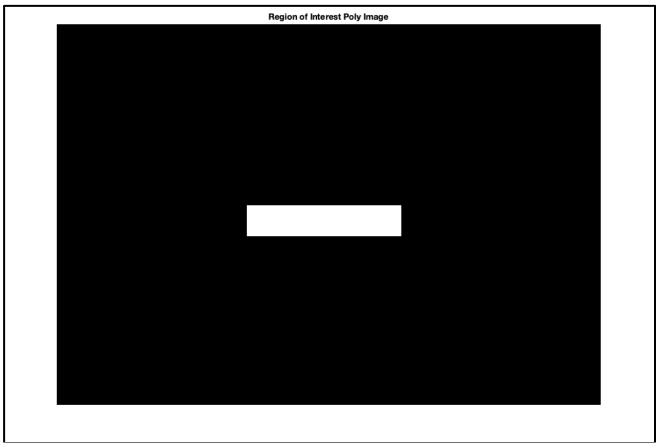

Figure 14 Region Of Interest Poly Image(As mask)

C. Image Morphological Analysis and Geometry:

1. The technique of morphing involves smoothing out the area of interest using morphological processes to change an object's shape from one form to another.
2. In order to process the images using forms, morphological techniques utilise a structuring element.
3. The smoothing procedure is finished once the unwanted pixels have been eliminated from the surface of the region of interest.
4. Image erosion and dilation are examples of morphological procedures.

Locating Area of Interest:

```
[r, c, m]=size(final_filtered);
x1=r/2; %height of image/2 > r/2 < rows
y1=c/3; %width of image/3 > c/3 < coloumns

row=[x1 x1+200 x1+200 x1];%row coordinates >
%making rectangle around only kidney stone area
col=[y1 y1 y1+40 y1+40];%coloumn coordniates

poly_image=roipoly(final_filtered,row,col);
%roipoly Select polygonal region of interest.
  % Use roipoly to select a polygonal region of interest within an
  % image. roipoly returns a binary image that you can use as a mask for
  % masked filtering.
figure;
imshow(poly_image),title('Region of Interest Poly Image');
```

```
%%apply this poly_image as mask with final filtered image
stone_image=final_filtered.*double(poly_image);
figure;
imshow(stone_image),title('Kidney stone image');
```

Apply above image as mask on filtered image

```
%%binary object has more than 4 pixels than only
final_stone_image=bwareaopen(stone_image,4);
[ya, num]=bwlabel(final_stone_image);
if(num>=1)
   disp('Stone is Detected');
else
   disp('No Stone is detected');
end
```

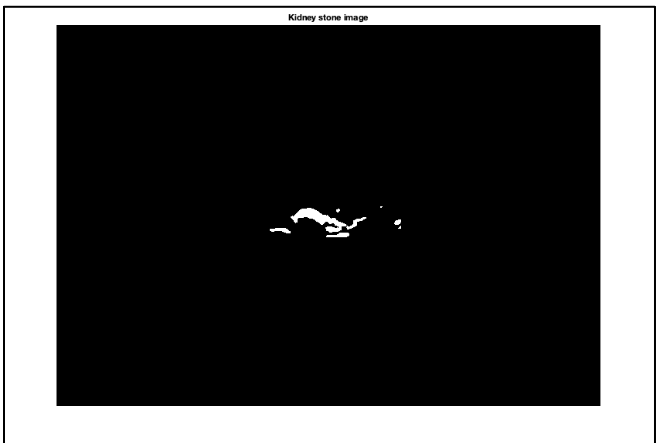

Figure 15 Kidney Stone Image

Result of MATLAB : Stone is Detected

➔ *Input Image which doesn't have kidney stone:*

All steps will be same as discussed in above sections.

Results of Main Parts of Techniques:

Figure 16 Sample UV Image

Figure 17 Pre-processed Image

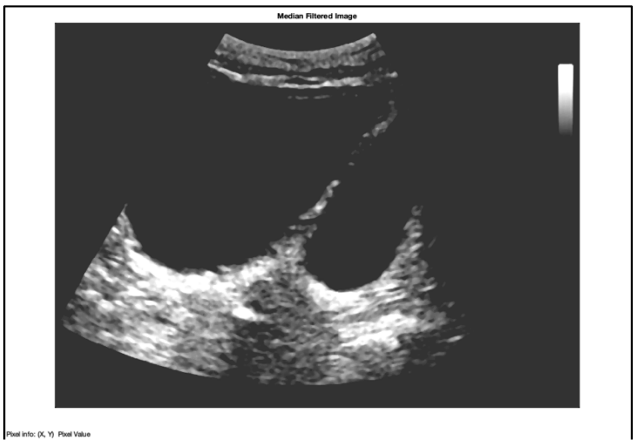

Figure 18 Median Filtered Image

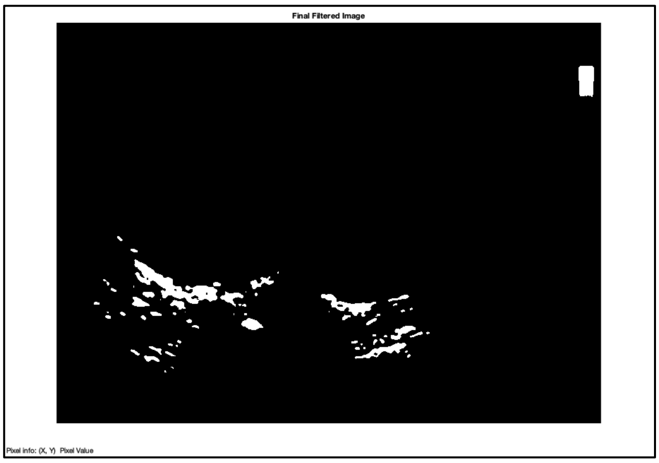

Figure 19 Final Filtered Image

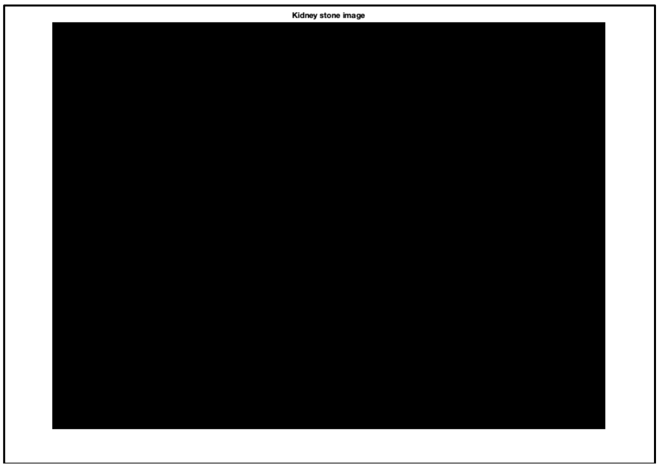

Figure 20 No Stone in Kidney Stone Image

Result Of MATLAB: No stone is detected

IV. CONCLUSION AND FUTURE WORK

The ultrasound image must first go through pre-processing, segmentation, and morphological analysis in order to be used in the suggested approach for detecting the presence of kidney stones.

The generated image was used to determine the exact location of the stone as well as its structure and shape using the geometry and thresholding method. A precise strategy for diagnosing kidney stones was produced by carefully combining these three procedures. The accuracy of the suggested algorithm is sufficient at roughly 90% when compared to earlier conventional methods (as tested with other UV images). In the future there are advanced methods such as wavelet based processing and fuzzy logic algorithms. The best features for use were found to be multi-scale wavelet-based processing.

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