Journal of Positive School Psychology http://journalppw.com
2022, Vol. 6, No. 6, 7643-7653

Stone Detection In Kidney With Image Processing Technique: CT Images

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Abstract- In this investigation, a deep analysis of stone detection in kidneys with image processing techniques using CT images was examined. This is one of the important issues over the world to detect the proper location of stone throughout the kidney. In the human system, two kidneys play an important role in purifying water and recycling it. In this research four stages were examined image preprocessing using median filter, segmentation with k- mean clustering algorithm, detection of kidney stone, and classification. Data collected around 40 patients from the hospital using a CT scanning machine, which diagnosis kidney stone diseases. This research explores the advanced technique to detect boundary, segmented area, and enhance detection of stone location from the kidney. This investigation helps in identifying the location of stone based on pixels. It also identifies the number of patients facing problems with the stone. The investigation shows this research has 92.5% accuracy with an effective stone detection technique.

Keyword- Kidney, Stone detection, CT Image, Segmentation, K- mean clustering.

1. Introduction

A kidney stone is one of the important research studies in the world. In that the formulation of kidney stones, calcium is more common among them. Many people are suspect of kidney stone problems [1]. The majority of kidney stone patients are undetected. The patients are not aware of the problem because of internal damage except extreme pain abdominally or urine color changes are absorbed [2]. To receive the appropriate medical treatment it is very important to continuously monitor the issue and keep testing to avoid further damage to the body. If stone detected earlier it will help in preventing and recovering at an earlier stage. Kidney stones decrease the functioning and dilation of the human body [3]. For the chronic disease of the kidney, it has implications. Many people are facing difficulties over body purification and circulation. Healthy Kidney makes people happier and healthier. The patients those who have kidney stone faces regular pain and weakness over time [4]-[5].

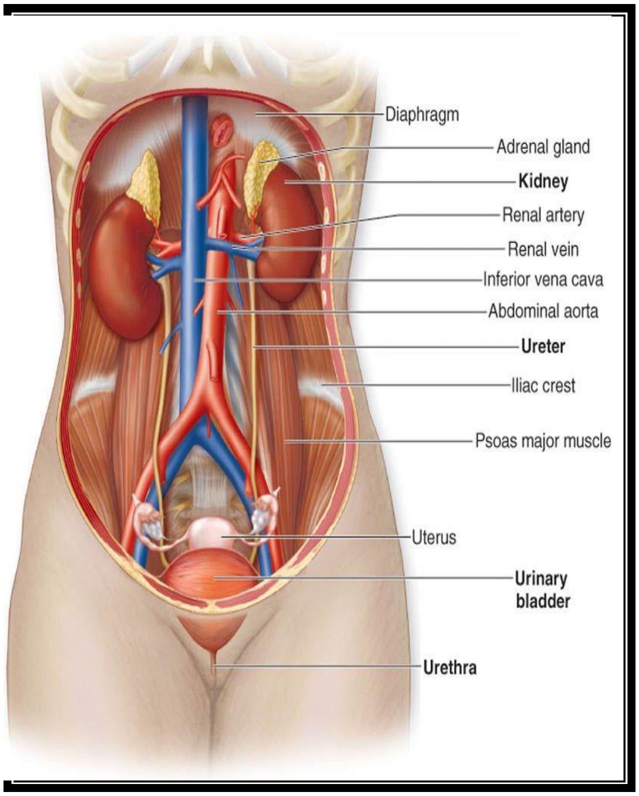


Figure 1- Kidney location in Human Body

Now a day's, tools come up with computer-assisted such as computed tomography, X-rays, and an ultrasound image. These tools are the most useful diagnostic tools for the diagnosis and screening of kidney stones [6]. In this research, a CT scan screening image has been considered for testing patients based on kidney stones detection. CT scan provides a Region of Interest (ROI) during the detection of stone location. Its efficiency and convenience in stone location position for both symptomatic and asymptomatic patients based on advanced CT screening technology [7]-[8]. According to CT screening images, software-based technology also play an important role in the detection of stone through the kidney [9]-[10]. Signs and symptoms of the human body with the presence of stone are intermittent pain (one of the highest and stronger pain is renal colic). It is caused by a stone in the kidney which is commonly highlighted restlessness, urinary urgency, sweating, hematuria, nausea, and vomit. Typically pain persists for 50- 60 mints for the effected patient [11]-[13].

For stone formation dehydration is the major factor which plays an important role in human health [14]-[15]. Intake of less quantity of water in high temperature and humidity may create dehydration in the human body because of those 80% chances of stone formation rate increases [16]. As of research high intake of sodium, honey including sugars, fructose based syrup, and consumption of fruit juices and tea increase the risk of stones in the kidney due to an increase in uric acid excretion and elevated urinary oxalate level [17]-[18]. Stones in the kidney can result in metabolic situations, such as tubular acidosis distal renal, hyperparathyroidism, dent's disease, primary hyperoxaluria, or sponge kidney [19]-[20].

Table 1: Composition

KIDNEY STONE TYPE	POPULATION	CIRCUMSTANCES	COLOR	SENSITIVITY	DETAILS
Calcium oxalate	80%	when urine is acidic (decreased pH)	Black/ dark brown	Radioopaque	Some of the oxalate in urine is produced by the body. Calcium and oxalate in the diet play a part but are not the only factors that affect the formation of calcium oxalate stones. Dietary oxalate is found in many vegetables, fruits, and nuts. Calcium from bone may also play a role in kidney stone formation.
Calcium phosphate	5–10%	when urine is alkaline (high pH)	Dirty white	Radioopaque	Tends to grow in alkaline urine especially when proteus bacteria are present.
Uric acid	5–10%	when urine is persistently acidic	Yellow /reddish brown	Radiolucent	Diets rich in animal proteins and purines: substances found naturally in all food but especially in organ meats, fish, and shellfish.
Struvite	10–15%	Infections in the kidney	Dirty white	Radioopaque	Prevention of struvite stones depends on staying infection-free. Diet has not been shown to affect struvite stone formation.
Cystine	1–2%	Rare genetic disorder	Pink /yellow	Radioopaque	Cystine, an amino acid (one of the building blocks of protein), leaks through the kidneys and into the urine to form crystals.

Table 1 shows detail about kidney stone types, population, circumstances, color, sensitivity, and details about stones in kidneys available in human bodies.

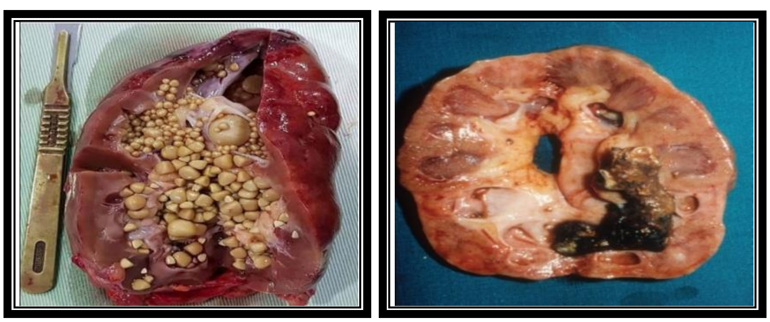


Figure 2- Presence of Kidney stones

Figure 3- Presence of Kidney stones

2. Methodology

These studies investigate four stages, image preprocessing, segmentation of image using k-mean clustering, detection of stone location through the kidney, and classification. Data collected around 40 patients from the hospital using a CT scanning machine, which diagnosis kidney stone diseases and help in identifying the number of patients facing problems of stone in the kidney.

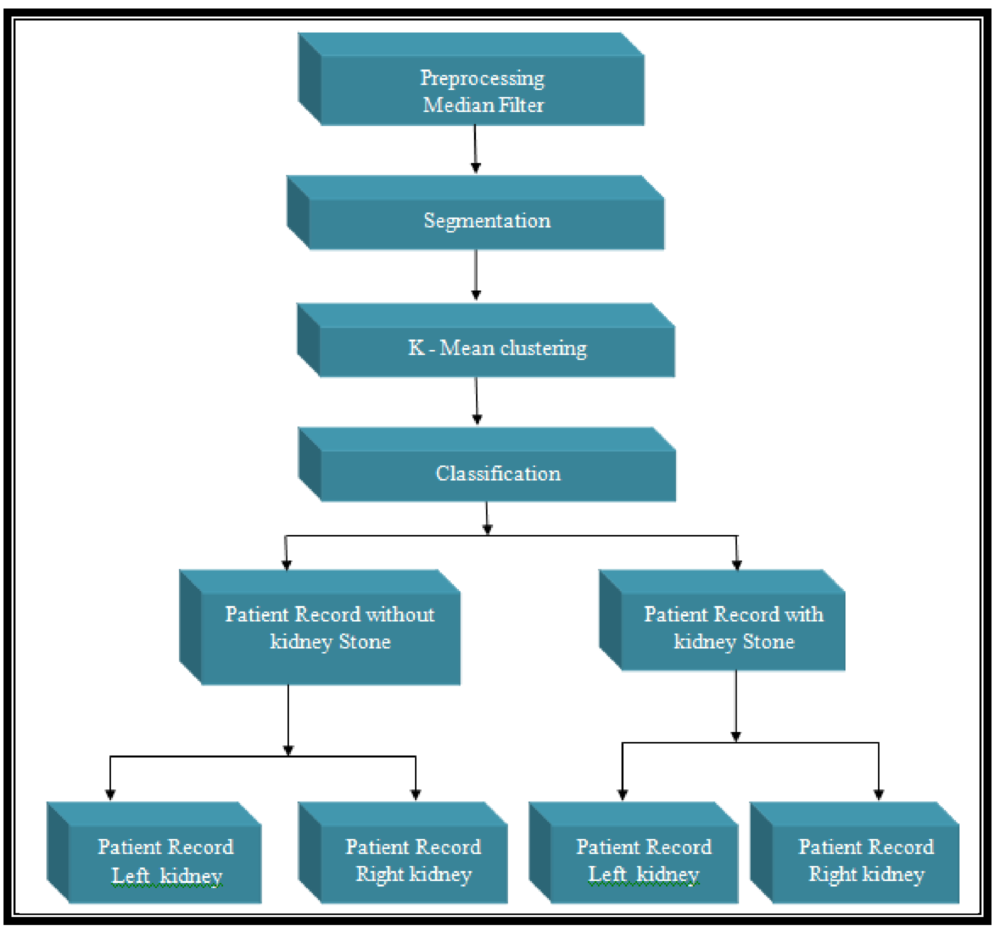


Figure 4- Methodology Flow Chart

3. Preprocessing using Median Filter

Preprocessing is a method for removing background noise from images. To remove noise from CT scan images the median filter is used. Median filters play an important role in removing noise from images. The median filter is a non-linear statistical filter, which describes in spatial domain form. It is smoothing, CT scan images by utilizing the median value of the neighborhood pixels over the image. In the processed image median filter perform two tasks. Firstly all pixels in the neighborhood and the original image are sorted in ascending value orders. Secondly, the sorted median value computed and chosen as the pixel value for the processed image.

Median value using 3x3 masks the given matrix shows the marked computed pixel calculation

Matrix form with 3x3 Masks $\begin{bmatrix} 1 & 5 & 7 \\ 2 & 4 & 6 \\ 3 & 2 & 1 \end{bmatrix}$

Step1: Firstly pixel value arrange in ascending order

1	1	2	2	3	4	5	6	7

Step2: Secondly the median value computed based on pixel order

1	1	2	2	**3**	4	5	6	7

In this matrix calculate the median value is 3 which is computed after steps 1 and 2. Then the original pixel values will be replaced and change to processed values.

$$\begin{bmatrix} 1 & 5 & 7 \\ 2 & 4 & 6 \\ 3 & 2 & 1 \end{bmatrix} \qquad \begin{bmatrix} 1 & 5 & 7 \\ 2 & \mathbf{3} & 6 \\ 3 & 2 & 1 \end{bmatrix} \longrightarrow$$

Original Image Median filter Image

When the median filter used to a CT scan image, then the pixel values which are very different from each other are eliminated from the process. By eliminating it select the most nearer pixel from the neighborhood value the process repeats until it achieves the noise-free images.

4. Segmentation

In the segmentation method, it helps to detect the region of interest area for the particular image which needs to be examined. The main objective of image segmentation is to find out region-based interest over the image. Segmentation steps involve split methods which help the image to split into the equal region or called as a unit. For iteration, it involves a split and merges process. Firstly, iteration split the region into different parts of the region then it followed by the merging process. In segmentation, the threshold value is set to 0.1.

<table>
<tr><td>R_1</td><td colspan="2">R_2</td></tr>
<tr><td rowspan="2">R_3</td><td>R_{41}</td><td>R_{42}</td></tr>
<tr><td>R_{43}</td><td>R_{44}</td></tr>
</table>

R_{11}	R_{12}	R_{21}	R_{22}
R_{13}	R_{14}	R_{23}	R_{24}
R_{31}	R_{32}	R_{41}	R_{42}
R_{33}	R_{34}	R_{43}	R_{44}

Table 1- Splitting of Image

5. K-mean cluster Algorithm

It is also called an unsupervised classification method. It does not consist of any training data. K means clustering algorithm is an iterative method in which algorithm clusters pixels value iteratively by computing intensity of mean value for the given classes and segment the pixel by classifying its closest mean from each pixel value.

Initially select K as Clusters $m_1(1)$, $m_2(1)$,…………. $M_n(l)$
(1)

In k^{th} iterative step, based on relation distribute pixel x on 'K' clusters, it is represented as

$p \in C_j(k) \quad \text{if} \; \| p - m_j(k) \| < \| p - m_i(k) \|$

(2)

For i≠j, i= 1,2,…….K, where $C_j(k)$ represent cluster center with set of pixel is $m_j(k)$

Compute cluster with new centers $m_j(k+1)$, j=1, 2,……..K, so that sum of the square distance from each pixel in $C_j(k)$ is minimized to a new cluster. The measure taken to minimize pixel value is the sample mean value of $C_j(k)$. Based on this new cluster center is represented as

$$C_j(k+1) = \frac{1}{Q_j} \sum_{x \in Cj(k)} R, \; j = 1, 2, \ldots\ldots K \qquad (3)$$

Where Q_j denote sample number in $C_j(k)$

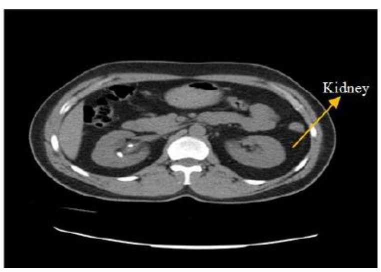
If the condition $C_j(k+1)$, j = 1, 2,……K, the steps terminated and algorithm converge or else repeat step 2.

(4)

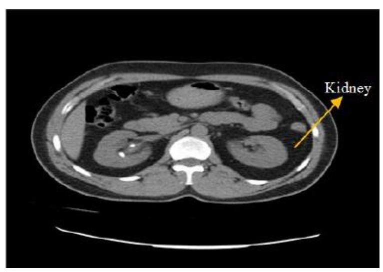
In this detection process, it examines the location of kidney weather stone is located on the left-hand side or right-hand side of the human kidney.

6. Results and Discussion

The result display stone detection in kidneys with image processing techniques using CT images. Four stages were examined image preprocessing using median filter, segmentation with k- mean clustering algorithm, detection of kidney stone, and classification. Data collected for testing around 40 patients from the hospital using a CT scanning machine, which diagnosis kidney stone problems.

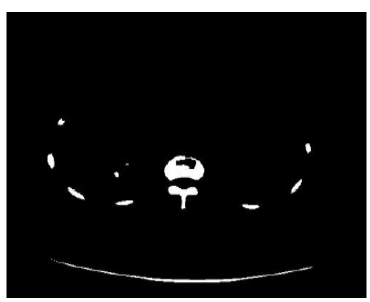


(a)



(b)

(c)



(d)

Figure 5- Resulted Images

Figure 5- The resultant image represents a) CT scan image which considered for testing stone, b) Preprocessed image with stone, c) segmentation results, d) detection of stone from kidney. The resultant image represents stone in the kidney after applying image processing techniques. This research explores the advanced technique to detect boundary, segmented area, and enhance detection of stone location from the kidney. The output represents kidney stones with white color and remaining portions with dark colors. This paper contains a sample image of patient ID - 1038, output results with 2 kidney-Left stone detection, and right kidney without stone detection.

Table 2 shows the analysis of the diagnosed patient's record without kidney stones. Table 3 also represents the analysis and result of a diagnosed patient record with a kidney stone. It identifies the location of stone based on pixels and also it identifies the number of patients facing problems with the stones with 92.5% accuracy. Accuracy is calculated using a confusion matrix which helps in determining values of false positive, true positive, false negative, and true negative results. For testing 40 CT scan patient report collected. Initially, the images are clustered into two groups. Group 1 without kidney stone and group 2 with kidney stone analysis. In which group 1 contains 10 patients which are healthy in position by examining both sides of kidney _left and kidney _right and group 2 contains 30 patients which are unhealthy in position by examining both sides of kidney _left and kidney _right using classification method. Group 2 also classifies several stones present by mean of count to kidney _left and kidney _right. In table 3 total number of patient is 30 in which two patients found no stone problems in right-hand-side of the kidney and 2 stone found in the left side of the kidney for patient ID 1038 and ID 1040 during the research and remaining 28 patients found with kidney problems.

TABLE 2- Analysis and Result of Diagnosed Patient Record without Kidney Stone

Patient Id	Information Recorded		Output	
	Kidney-LEFT	Kidney-RIGHT	Kidney-LEFT	Kidney-RIGHT
1001	CLEAR	CLEAR	NO	NO
1002	CLEAR	CLEAR	NO	NO
1003	CLEAR	CLEAR	NO	NO
1004	CLEAR	CLEAR	NO	NO
1005	CLEAR	CLEAR	NO	NO
1006	CLEAR	CLEAR	NO	YES
1007	CLEAR	CLEAR	NO	NO
1008	CLEAR	CLEAR	NO	NO
1009	CLEAR	CLEAR	NO	NO
1010	CLEAR	CLEAR	NO	NO
1011	CLEAR	CLEAR	NO	NO
1012	CLEAR	CLEAR	NO	NO
1013	CLEAR	CLEAR	NO	NO
1014	CLEAR	CLEAR	NO	NO

1015	CLEAR	CLEAR	NO	NO

Table 2 shows the analysis of the diagnosed patient's record without kidney stone, which is considered as group 1 with 10 patients which are healthy in position by examining both sides of kidney _left and kidney right based on classifications.

TABLE 3- Analysis and Result of Diagnosed Patient Record with Kidney Stone

Patient Id	**Information Recorded**		**Output**	
	Kidney-LEFT STONES	**Kidney-RIGHT STONES**	**Kidney-LEFT STONES**	**Kidney-RIGHT STONES**
1016	1 STONES PRESENT	2 STONES PRESENT	YES	YES
1017	3 STONES PRESENT	2 STONES PRESENT	YES	YES
1018	2 STONES PRESENT	2 STONES PRESENT	YES	YES
1019	1 STONES PRESENT	NO STONE DETECTED	YES	YES
1020	3 STONES PRESENT	1 STONES PRESENT	YES	YES
1021	2 STONES PRESENT	1 STONES PRESENT	YES	YES
1022	1 STONES PRESENT	2 STONES PRESENT	YES	YES
1023	3 STONES PRESENT	2 STONES PRESENT	YES	YES
1024	1 STONES PRESENT	1 STONES PRESENT	YES	YES
1025	2 STONES PRESENT	1 STONES PRESENT	YES	YES
1026	3 STONES PRESENT	2 STONES PRESENT	YES	YES
1027	3 STONES PRESENT	2 STONES PRESENT	YES	YES
1028	1 STONES PRESENT	3 STONES PRESENT	YES	YES
1029	2 STONES PRESENT	4 STONES PRESENT	YES	YES
1030	3 STONES PRESENT	2 STONES PRESENT	YES	YES
1031	3 STONES PRESENT	2 STONES PRESENT	YES	YES
1032	1 STONES PRESENT	3 STONES PRESENT	YES	YES
1033	4 STONES PRESENT	5 STONES PRESENT	YES	YES
1034	4 STONES PRESENT	1 STONES PRESENT	YES	YES
1035	5 STONES PRESENT	2 STONES PRESENT	YES	YES

1036	1 STONES PRESENT	1 STONES PRESENT	YES	YES
1037	3 STONES PRESENT	1 STONES PRESENT	YES	YES
1038	2 STONES PRESENT	NO STONE DETECTED	YES	**NO**
1039	3 STONES PRESENT	2 STONES PRESENT	YES	YES
1040	2 STONES PRESENT	NO STONE DETECTED	YES	**NO**

Table 3 represents the analysis and result of the diagnosed patient recorded with kidney stones. It identifies the location of stone based on pixels and also identifies the number of patients facing problems with the stones. Group 2 contains 30 patients which are unhealthy in position by examining both sides of kidney _left and kidney _right using classification method. The below table 4 represents accuracy using a confusion matrix which helps in determining values of false positive, true positive, false negative, and true negative results. For kidney stone detection the number of patients used is 40. In which actual values counts are 23 cases with true positive, 1 case with false positive, 2 cases with false-negative, and 14 cases with true negative values calculated with 92.5% accuracy. The total number of patients with kidney stone problems is 30 patients and 10 patents are in healthy state position recorded.

TABLE 4- CONFUSION MATRIX FOR KIDNEY STONE DETECTION

Outcome	**ACTUAL VALUE**	
	23 cases True Positive	1 case False Positive
	2 cases False Negative	14 cases True Negative
Table 2	(Cases based on correct detection x 100) ÷ Total Cases	Table 2 = (14 x 100) ÷15 = 93.3%
Table 3	(Cases based on correct detection x 100) ÷ Total Cases	Table 3 = (23 x100)÷ 25= 92 %
TPV (True Positive Value)	(True Positive ÷ All given Positive samples)	TPV= 23 ÷ (23 + 1) = 0.95 = 95%
FPV (False Positive Value)	False Positive ÷ All given Negative samples	FPV = 1 ÷ (2 + 14) = 0.0625= 6.25%
ACCURACY	(True Positive Value + True Negative Value) ÷ (Total Samples)	Accuracy = (23+ 14) ÷ (40) = 37 ÷ 40 = 92.5%

Table 3, It consists of actual values, with table 1 records of without having kidney stone patients, table 2 with kidney stone patients, true positive value calculation, false-positive value calculation and overall accuracy with classification. Table 1 values of patient calculated as cases based on correct detection into a hundred divided by a total number of patients in table I without kidney stone. Table 2 value is calculated as total cases based on correct detection into a hundred divided by the total number of cases in table 2 with kidney stone patients. To calculate TPV value is given as the true positive value divided by all given positive samples. Now calculate FPV it is denoted as false-positive divided by all given negative samples. Now calculate accuracy it is given as true positive value-added with true negative value divided by a total number of samples value.

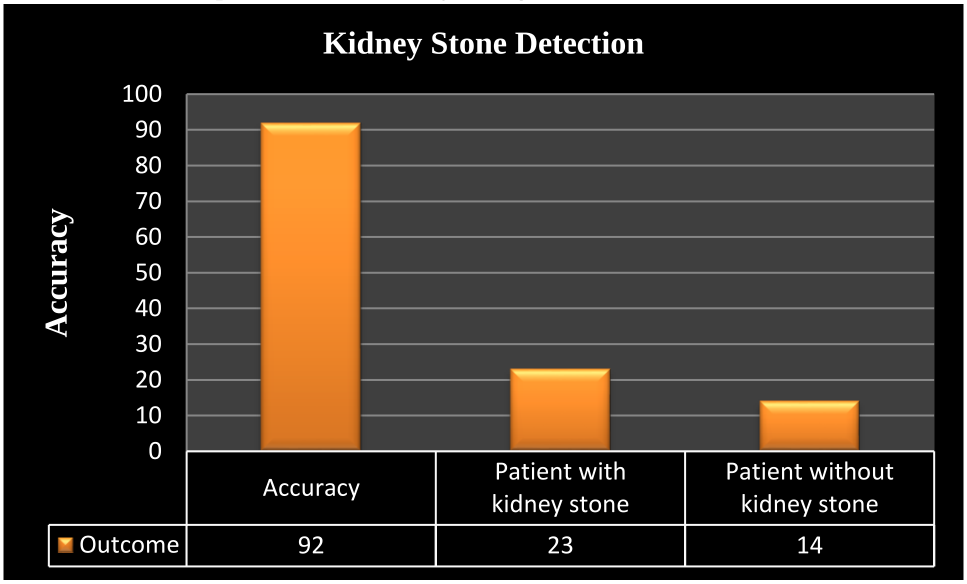


Table 5 – Represents the accuracy of kidney stone detection with overall outcomes, patients with kidney stone, and without kidney stone by using graphical mapping.

Conclusion

This investigation work with deep analysis of stone detection in kidneys with image processing techniques using CT images was examined. This is one of the important issues over the world to detect the proper location of stone throughout the kidney. In this research, four stages were examined image preprocessing using median filter, segmentation with k- mean clustering, kidney stone detection with location type using classification technique. A total number of data collected around 40 patients from the hospital to diagnosis kidney stone problems. This research explores the advanced technique to detect boundary, segmented area, and enhance detection of stone from the kidney with present locations left or right. The investigation ensures this research has 92.5% accuracy with an effective stone detection technique using image processing.

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