Kidney Stone Detection with CT images using Fuzzy-C Means Clustering

Veeramachaneni Indu ,
Department of IT
BVRIT Hyderabad College of Engineering for Women,
Hyderabad,India.
veeramachaneniindu@gmail.com

Pitla Nikitha,
Department of IT
BVRIT Hyderabad College of Engineering for Women,
Hyderabad,India.
nikithapitla@gmail.com

Subetha T,
Department of IT
BVRIT Hyderabad College of Engineering for Women,
Hyderabad,India.
subetha.t@bvrithyderabad.edu.in

Abstract— The kidney is a primary source organ for excretion, and the normal process of kidneys is affected by kidney stones. Kidney stones are detected using Computed Tomography (CT) scans. CT scans the stomach area to see stones inside the kidney, and it is saved as images on the computer. Automated detection of kidney stones is done for better diagnosis of the person at an early stage. The significant issues that affect the performance are the low contrast image and the noise present in the image. To resolve those issues, an automatic kidney stone detection based on an image processing technique is proposed. Here the images are trimmed and given to the segmented process. The proposed work is utilized to find kidney stones by the use of the level set segmentation method. At first, input images are preprocessed, and the area of interest is segmented. The level set segmentation detects the arbitrary shapes of the stones better than the other algorithms. As the CT scan image has some fuzziness, the Fuzzy C-Means Clustering technique is utilized to outperform the existing algorithm. Comparative results show that the proposed system performs well than the current system.

Keywords— Image processing, level set segmentation, Fuzzy C-Means clustering, Image localization

I. INTRODUCTION

Kidney stones [1] are the solid deposition of ore and acid salts that adhere in coalesce urine. They can be agonizing when they go through the urinary tract and can lead to some severe conditions. Kidney stones, when enduring unseen in the germinal stage, corrodes the kidney as they form. Proper Localization of kidney stones at the early stage helps the doctor diagnose the disease. The advancement of CT Scan image processing has led various researchers to predict accurate results despite various issues.

Though CT scan imaging[2] provides accurate results, detecting and localizing the shape and location of the renal calculi automatically is a challenging task. Automating this provides various advantages, such as it helps the doctor in surgery, finding the shape of the stone, finding the stone's location, etc. The main challenges that affect the performance of this detection are handling noise in the image, detect the size of the stone and the location of the stone. Several authors are using various image processing techniques to identify and locate the shape of the renal calculi. The general architecture for kidney stone detection is given below.

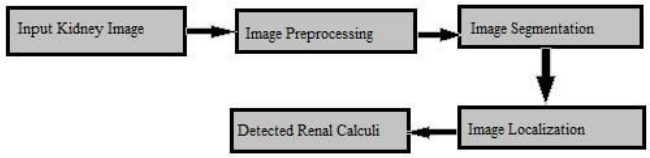

Figure 1: General Architecture

The system generally acquires the human kidney image acquired using CT Scan imaging[3]. The acquired image is processed using various preprocessing techniques to remove the noise from the image. The preprocessed image is given to image segmentation module where numerous segmentation algorithms are applied on the image to obtain the shape of the stone. After detecting the shape of the stone, image localization is performed to locate the position of the stone in the kidney. This technique helps the doctor during their diagnosis.

In this paper, the proposed system uses level set segmentation and fuzzy c-means algorithm to segment and localize the renal calculi. The paper is structured as follows. Section II describes about the related works of renal calculi detection. Section III depicts about the methodology. Section IV describes about comparative results followed by conclusion in Section V.

II. RELATED WORKS

Several related works are done in the area of image processing and machine learning. This section reviews some of the recent associated works published in this area. Prema et al. [4] proposed a Kidney Stone Detection using a semi-automatic segmentation approach. This approach takes an image of a Human kidney via ultrasound and using the Seeded Region Growing technique. The main advantage of this technique is the ability to handle noise in the image and the disadvantage of this method is that the requirement of an initial input image.

Tamilselvi et.al[5] proposed a fully automatic algorithm to detect quantification of kidney stones using symmetric analysis. Web method involves mainly three steps; Detection of renal stones segmenting, the renal area, and calculating the area surrounding the stone. The Seeded Region Growing algorithm and contour-based Squared Euclidean distance method are used for segmentation. ANFIS supervised learning has proven to be significantly more effective. Since then, the authors have introduced many enhancement techniques applied to CT images of this kind to see which method is the most suitable. Morphological and Median filtering approaches are also used to find the renal calculi in the CT scan images of the kidney.

The Speckle Noise is reduced using a Gaussian Low-pass filter[6]. The Texture Analysis has multiple steps; they are: finding the local entropy of the organ within the image, the threshold selection, the morphological operations, the object windowing, the determination of seat point, and lastly, the ROI generation. The authors have also proposed a region indicator with a control segmentation method. Although the technique is a little complex, it provides the expected accuracy in Kidney Stone detection. The authors have also proposed a computer aided system for early stone detection in kidneys. Depending on the stone size, the classification is done whether the stone is early or regular.

III.METHODOLOGY

The proposed system identifies and localizes the renal calculi using the CT scan image. The processing steps of the proposed method are given below. The system acquires the image from a CT scan and preprocesses the image. The preprocessing step consists of cropping the image into the required dimensions. Our methodology lies in preprocessing, level set segmentation, fuzzy c-means, and analysis of stone with the location. The overall system architecture is shown in Figure 2.

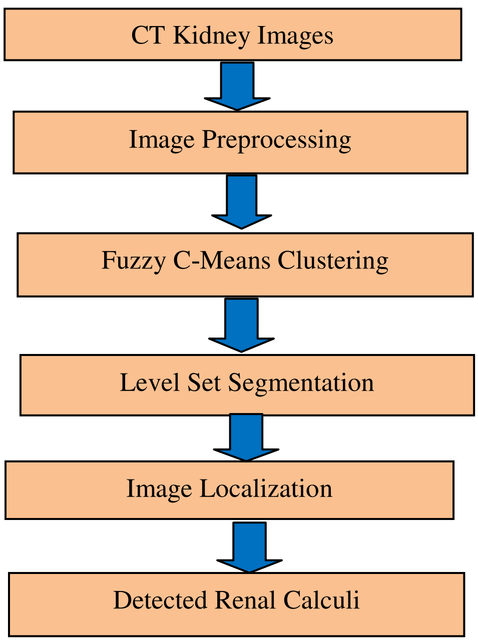

Fig.2 Proposed System Architecture

A. CT Kidney Images

The CT Scan images are taken from the icon data set, consisting of 50 kidney stone images of various patients. The CT image part consisting of the kidney stone region is chosen and stored independently for each patient. The sample dataset image is shown in Figure 3.

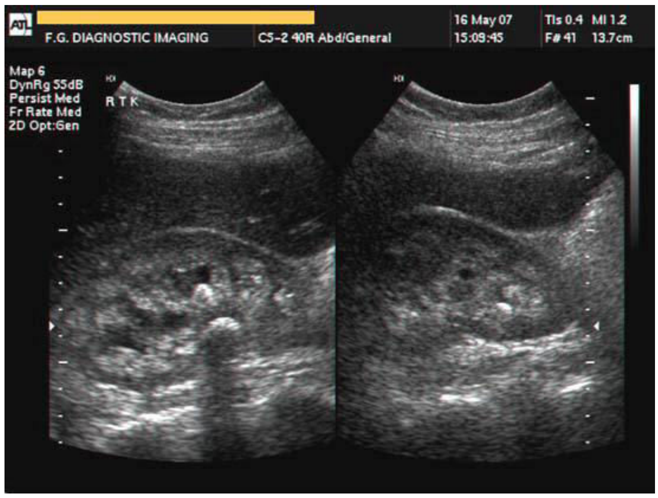

Fig.3 CT Scan Image []

B. Preprocessing of Images

The CT Scan images represent the kidney regions in the center. The preprocessing step consists of trimming the image to obtain a cropped image. The algorithm for cropping the image is given below and the sample image is given in Figure 3.

Algorithm: trimming CT image
Input: CT image of the kidney
Output: enhanced image
Start:
Step1: Read greyscale image and matrix of that image
Step2: Initialize row sum as Y
Step3: Calculate the row sum of the matrix
Step4:Compare and retain the value greater than 20(threshold) from the matrix obtained from step3.
Step5: Initialize column sum as X
Step6: Calculate the column sum of the matrix
Step 7: Compare and retain the value greater than 1000 (threshold) from the matrix obtained from step6.
Step8: Apply median filtering
Step 9:returns a new enhanced image
End

C. Fuzzy C-means Clustering(FCM)

FCM[8] provides good outcomes for overlapped data sets and is relatively better than the k-means algorithm. It is one of the most commonly used algorithms in clustering, and many medical images have enforced it. The FCM is more than an adequate method for clustering because it allows a single slice of data to belong to many clusters, and it is used for structure recognition. The objective function for FCM is based on the following equation

Js=∑Tp=1∑Dq=1 vspq||Yq-Dq||2 , 1≤σ<∞ (1)

In the above equation 1, s can be any real number that is greater than 1. Vpq is the degree of enrollment of Yq in the cluster q, Yp is the path of d-dimensional measured data, Dq is the d-dimensional center of the cluster, and ||Yp-Dq|| is any standard expressing the similarity between consistent data and the center. The algorithm to perform fuzzy c-means clustering is given in Algorithm 2. To perform fuzzy separation, iterative optimization of the objective function is shown above, with the update of the membership Vpq and the cluster centers Ck are given in equation 2.

$$v_{pq} = \frac{1}{\sum_{i=1}^{D} \left[\frac{g_p - dq}{x_i - C_k}\right]^{\frac{2}{S-1}}} \qquad (2)$$

$$Dq = \frac{\sum_{p=1}^{T} v_{Pq}^{S} yp}{\sum_{P=1}^{\dot{T}} v_{pq}^{S}} \qquad (3)$$

This iteration will stop when $\max_{pq=}\left\{\left[vp_q^{(i+1)} - v_{pq}^{I}\right]\right\} <$ €, Where € is a exiting crierion between 0 and 1, wherras 1 is the Iteration steps.

Algorthm 2: Fuzzy c- means clustering
Input: CT trimmed image
Output: Cluster centers
Start :
Let us assume there is a set of data points.
Step1: Randomly select 'c' clusters.
Step2: Identify the fuzzy membership of those data points.
Step3: Compute the fuzzy centers of those clusters by using the centroid formula((a+b+c)/3).
Step4: Calculate the Euclidean distance from the centroid to each data point.
Step5: Repeat the above procedure until all the data points are clustered.
End

D. Level Set Segmentation

Level set Partitioning[9] is generally used in image segmentation, segmentation of motion, tracking of object etc. The Level set method depends on position and time for any given image. A level is created to describe the counter. The quantity is defined as the zero level set function Φ and it is given in equation 3.

D = {(a,b)|Φ(a,b) = 0 (3)

Inside the region and outside the region of the arc is given by line-short continued function Φ as shown in the equation 4,5,6 for the following properties:

Φ(a,b) > 0 Inside the Contour (4)

Φ(a,b) = 0 at the Contour (5)

Φ(a,b) < 0 Outside the Contour (6)

By varying the value of pi as shown in equation 4,5,6, some regions will become positive, negative, and some regions will turn to negative that are formerly positive. Hence, the contour will change location according to the updated value of the level set function.

E. Identification of Stone Location

The description of the CT kidney stone process depends on the segmentation results. Through the Level set segmentation algorithm, the presence of stones is detected. If stones are displayed in the kidney, then the size of that kidney varies by 2cm more than its original size.

Algorithm : Identifying the location of stone
Input: omputed tomography images of kidney
Output: segmented region of kidney representing calculi
Start:
Step1: read the given input image
Step2:trim the image by threshold value
Step3:fuzzy c-means clustering
Step4:extracting end most clusters
Step5: add pixels with intensity , nearer to the mean of the region
Step6: level set segmentation output
Step7: median filter
Step8: continue, until all pixels belong to some regions
End

In our proposed work, we are considering region parameter eradication for renal calculi pictures of the kidney. If the segmentation yields regions representing the renal calculi, region parameters for the renal calculi CT image are extracted. Region parameters are used for centroid, area and etc.

Centroid: -It detects the kidney centroid and it's usually represented by the center of mass of the kidney.

Area: -Area is a scalar capacity and it provides the number of pixels present in a particular area. area is calculated using the final results of the segmentation.

III.EXPERIMENTAL RESULTS

The proposed system is implemented in MATLAB 2018. The system takes CT scan images and the histogram is performed to identify the pixel range and the output is shown in Figure 4.

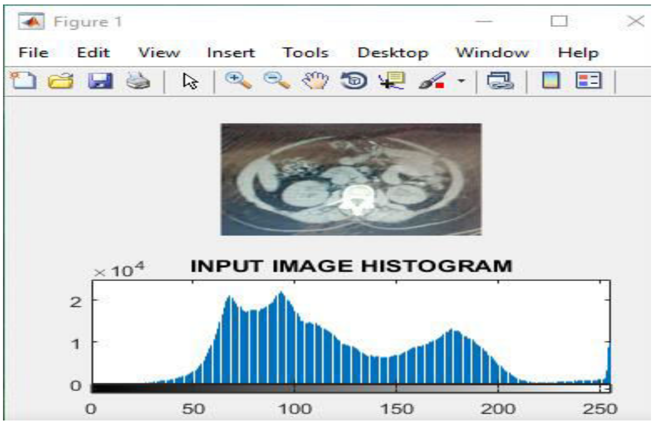

Fig 4. Input image histogram

Then, the input image is converted from the colour to RGB image for easy identification. The red ,blue and green pixels ranges are shown in Figure 5.

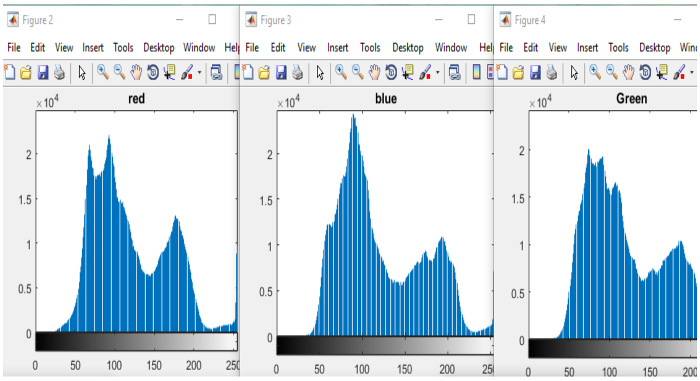

Fig 5. RGB pixel ranges

Noise addition is done for image enhancement and in this project salt and pepper noise is added to the input image. This results in the enlargement of image so that a small minute growing of stone could be clearly visible. After this noise addition, Median filtering [10] is performed on the RGB images for noise removal and the output is shown in Figure 6.

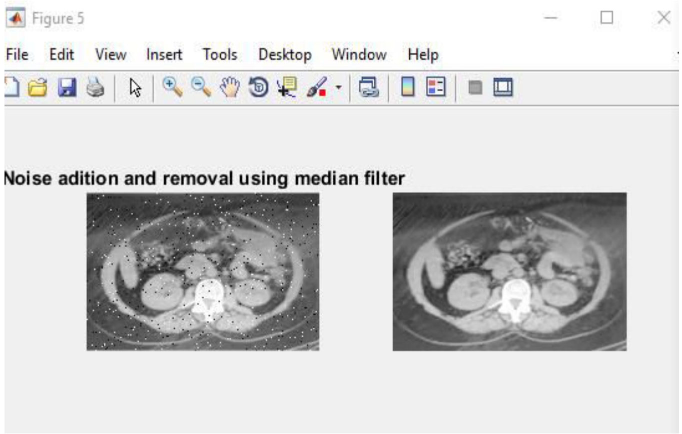

Fig 6. Addition of noise and removal of it

After the removal of noise, fuzzy c means clustering and level set segmentation is used to identify the location of stone and the output is shown in Figure 7 and Figure 8. .

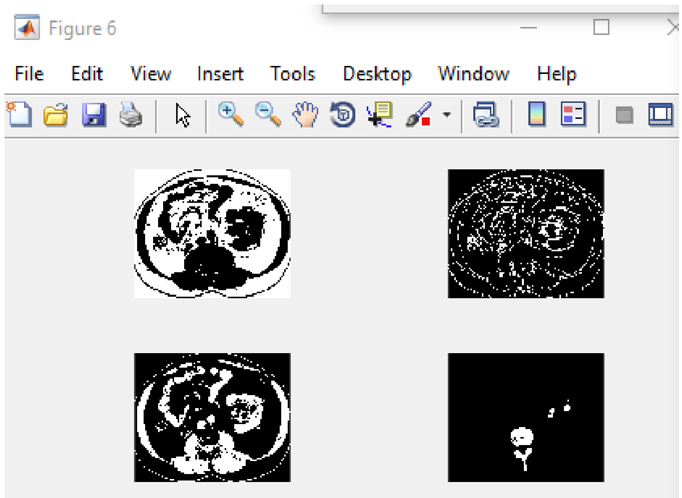

Fig 7. Level Set Segmentation

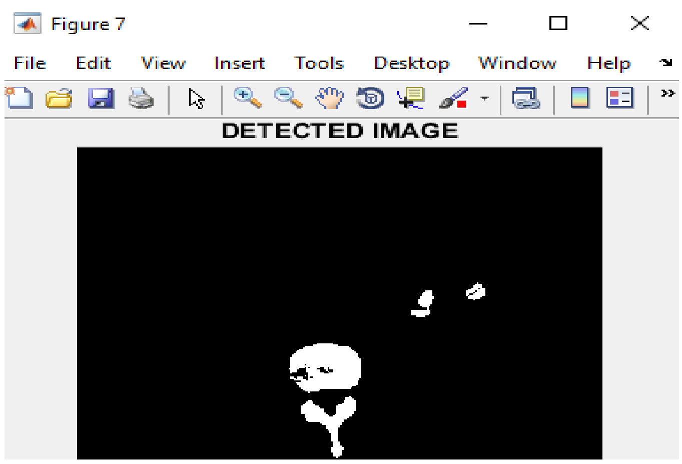

Fig 8. Detected image.

The information about the number of kidney stones and area of each stone. A sample input image which has stone area of

20 pixels and stone size 5.57mm. A sample calculi image has 2 stones of 30 pixels, size of the stones is 4.03mm and 6.23mm respectively and the summarized value is shown in Table 1.

Table.1 The area of kidney stones and location of the stones

Sample Images	Stone Location and Area		
	Number Of Stones	Total area (in Pixels)	Location of Stone(X,Y)
1	1	20	163.57,79.51
2	1	14	159.28,97.12
3	2	30	180.75,78.54

III. CONCLUSION

The proposed system detects and identifies the location of renal calculi using level set segmentation and fuzzy c-means clustering. The preprocessing step involves trimming the image and removal of noise using median filtering. The fuzzy c-means and level set segmentation is used to detect and identify the location of renal calculi. In the proposed work, results with regions and then region properties for those regions are extracted. The proposed system also finds the size and the location of each kidney images which have renal calculi. The proposed method is efficient with low computational complexity.

REFERENCES

1. Vineela, T., Akhila, R. V. G. L., Anusha, T., Nandini, Y., & Bindu, S. Kidney Stone Analysis Using Digital Image Processing.
2. Brisbane, W., Bailey, M. R., & Sorensen, M. D. (2016). An overview of kidney stone imaging techniques. Nature Reviews Urology, 13(11), 654.
3. Verma, J., Nath, M., Tripathi, P., & Saini, K. K. (2017). Analysis and identification of kidney stone using K th nearest neighbour (KNN) and support vector machine (SVM) classification techniques. Pattern Recognition and Image Analysis, 27(3), 574-580.
4. Akkasaligar, P. T., Biradar, S., & Kumbar, V. (2017, August). Kidney stone detection in computed tomography images. In 2017 International Conference On Smart Technologies For Smart Nation (SmartTechCon) (pp. 353-356). IEEE.
5. Tamilselvi, P. R., & Thangaraj, P. (2012). Segmentation of Calculi from Ultrasound Kidney Images by Region Indictor with Contour Segmentation Method. global journal of computer science and technology.
6. Tamiselvi, P. R. (2013). Segmentation of renal calculi using squared euclidean distance method. international journal of scientific engineering and technology, 2(7), 651-655.
7. Viswanath, K., & Gunasundari, R. (2014, September). Design and analysis performance of kidney stone detection from ultrasound image by level set segmentation and ANN classification. In 2014 International Conference on Advances in Computing, Communications and Informatics (ICACCI) (pp. 407-414). IEEE.
8. Yu, H., He, F., & Pan, Y. (2020). A scalable region-based level set method using adaptive bilateral filter for noisy image segmentation. Multimedia Tools and Applications, 79(9), 5743-5765.
9. Miao, J., Zhou, X., & Huang, T. Z. (2020). Local segmentation of images using an improved fuzzy C-means clustering algorithm based on self-adaptive dictionary learning. Applied Soft Computing, 91, 106200.
10. Tang, Hongshen, et al. "Median filtering detection of small-size image based on CNN." Journal of Visual Communication and Image Representation 51 (2018): 162-168.