Kidney Stone Detection in Computed Tomography Images

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Abstract—**The proposed work is used to detect the kidney stones by using Level set segmentation method. Initially input images are preprocessed and region of interest is segmented. The level set segmentation is a good method to solve the problem of segmentation successfully. Computed tomography scans are diagnostic tools that are used for many purposes. Basically, CT's send X-rays through the body in tiny slices, which are saved as images on the computer. The preprocessing of the CT images is carried out for cropping the input image. After preprocessing step the input image is segmented using level set segmentation technique. Finally the segmented images are analyzed to detect the size and location of the stone.**

Keywords— Kidney CT images, level set segmentation, FCM, Analysis

I. INTRODUCTION

Imaging has become most essential component in the biomedical and clinical research. Medical imaging is a technique that allows the physician to create a visual representation of interior organs. They are later used for the clinical analysis and medical intervention. The wide varieties of medical imaging modalities are available to treat and diagnose the disease. For our study we have considered the CT imaging. In human beings, kidney is the most silent organ. There is a pair of bean shaped organ called kidneys and are situated at the rear side of abdominal cavity in the retroperitoneal space. Kidney carries out two important functions like removing harmful substances from the blood and it keeps the useful components in a proper balance. Few of the abnormalities that we can usually find in kidney are congenital kidney disease, kidney infection, diabetic nephropathy, polycystic kidney dieses, tract infection and kidney stone [1]. The most common abnormality that occurs in human urinary system is kidney stone or renal calculi. Stone is a pebble like structure formed by the solid concretion or crystal aggregation by the dietary mineral components in the kidney. We can also classify the kidney stones based on their location as well as the chemical composition. Based on their chemical composition they are classified as calcium oxalate, uric acid, sturvite and cystine stones [2]. Based on their location kidney stones are classified as kidney (nephrolithiasis), ureter (ureterolithiasis) and bladder (cystolithiasis).

In [3], the authors have proposed kidney stone detection using semi automatic segmentation approach. They have described the semi automatic method for segmentation of kidney from ultrasound images by using seeded region growing. Seeded region growing is one of the good techniques for identification and classification of renal calculi because this method does not affected by speckle noise. This seeded region growing preserve the spatial information. It requires initial input to be provided by user. In [4], the authors have proposed fully automatic algorithm to detect quantification of kidney stones by using symmetric analysis. Initially region of interest has been generated. Their method involves mainly 3 steps: detection of renal stones, segmenting the renal area and calculates the area surrounded by stone. Seeded region growing algorithm is used for segmentation. In [5], the authors have proposed Contour Based Squared Euclidian Distance (CSED) segmentation method. In this method initially pre-processing is applied to reduce noise, Squared Euclidian Distance is determined between the training image centroid value and centroid value of selected region. Usage of ANFIS supervised learning has made technique little efficient. In [6], the authors have introduced many enhancement techniques and are applied to ultrasound images to see which technique is most suitable. They have concluded that morphological and median filtering provide better results for ultrasound images of kidney. In [7], the authors have proposed, automatic region of interest generation in kidney ultrasound images. The methods consist of the speckle noise reduction using Gaussian low-pass filter, texture analysis is done by finding the local entropy of the image, threshold selection, morphological operations, object windowing, determination of seed point and last but not least the ROI generation. In [8], the authors have proposed region indicator with contour segmentation (RICS) method. Initially the region indices are checked to see whether they are inside kidney region or not, if inside then those pixels are included in region indices set. It is a supervised and multiple thresholding method it is little complex but provides the expected accuracy. In [9], the authors have proposed computer aided system for early stone detection in kidneys. Depending on the stone size the classification is done as early stone or stone or normal. In [10], the authors have proposed new technique towards operator independent kidney ultrasound scanning. The presence of speckle noise makes the process difficult to identify the boundary and to find the accurate centroid. Authors work provide the automatic detection of

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centroid for the kidney and then made the segmentation technique easier.

The work consists of four sections. Section 2 represents the methodology. Section 3 is about experimental results. Finally conclusion of the present work is included.

II. Methodology

The methodology describes a method for identifying the renal calculi in the kidney CT images. The proposed method also helps in measuring the size and area of the kidney stones as well as the location of the kidney stone. Our methodology consists of pre-processing, level set segmentation and analysis of stone size along with location. This methodology is shown in Fig 1.

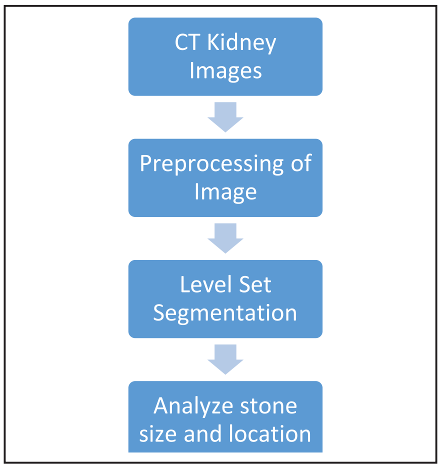

Fig 1. Representation of proposed work

A. CT Kidney Images

Image dataset consists of CT images of 50 patients. CT image slices consisting of kidney stone region is selected and stored separately for each patient.

B. Preprocessing of Images

Basically the CT images are consisting of kidney regions at the center part usually so we need to crop the input image, the below algorithm 2.1 shows the steps for cropping.

Algorithm: Cropping CT image

Input: CT images of kidney

Output: Cropped image

Start

Step 1: Read grayscale image and matrix of that image

Step 2: Initialize row sum as Y

Step 3: Calculate the row sum of the matrix

Step 4: Compare and retain the value greater than 20 (threshold) from matrix obtained from step 3.

Step 5: Initialize column sum as X

Step 6: Calculate the column sum of the matrix

Step 7: Compare and retain the value greater than 1000 (threshold) from matrix obtained from step 6.

Step 8: Returns new matrix based on that input image is cropped.

End

C. Fuzzy C-means Clustering (FCM)

FCM gives the good results for overlapped data set and comparatively better then k-means algorithm. It is one of the most widely used algorithms in clustering and it has been applied to many medical images. This FCM is very effective method for clustering because it allows single slice of data belong to many clusters and it is used for pattern recognition. This is based on the following objective function.

$$J_s = \sum_{p=1}^{T} \sum_{q=1}^{D} v_{pq}^{s} \left\|Y_q - D_q\right\|^2 \text{ , } 1 \leq \sigma < \infty \qquad (1)$$

where s is any real number that is greater than 1,v_{pq} is the degree of membership of y_q in the cluster q, Y_p is the pth of d-dimensional measured data, D_q is the d-dimension center of the cluster, and $\|Y_p - D_q\|$ is any norm expressing the similarity between any measured data and the center. Fuzzy partitioning is carried out through an iterative optimization of the objective function shown above, with the update of membership v_{pq} and the cluster centers c_k by:

$$v_{pq} = \frac{1}{\sum_{l=1}^{D} \left[\frac{\|y_p - d_q\|}{\|x_i - c_k\|}\right]^{\frac{2}{s-1}}} \qquad (2)$$

$$D_q = \frac{\sum_{p=1}^{T} v_{pq}^{s} \cdot y_p}{\sum_{p=1}^{T} v_{pq}^{s}} \qquad (3)$$

This iteration will stop when $max_{pq}\left\{\left|v_{pq}^{(l+1)} - v_{pq}^{(l)}\right|\right\} < \epsilon$, where ε is a termination criterion between 0 and 1, whereas l is the iteration steps.

Algorithm: Fuzzy c-means clustering

Input: Computed tomography images of kidney

Output: Cluster centers

Start:

1. Initialize V=[v_{pq}] matrix, $V^{(0)}$
2. At l-step: calculate the centers vectors $D^{(l)}$ =[d_q] with $V^{(l)}$, by using (3)
3. Update V^{l}, $V^{(l+1)}$,by using equation (2)
4. If $\| V^{(l+1)} - V^{(l)}\| < \varepsilon$ then stop; otherwise go to step 2.

end

D. Level Set Segmentation

Level set segmentation is generally used in image segmentation, segmentation of motion, tracking of objects etc.

Level Set methods depend on position, time. For any given image we can create a level set function ϕ (a, b) to describe the contour. The contour D is defined as the zero level set function ϕ:

$$D = \{(a, b) \mid \phi (a, b) = 0 \qquad (4)$$

Inside region and the outside region of the curve is given by line-shots continuous function ϕ as shown in equation (4), with following properties:

$$\Phi(a, b) > 0 \text{ Inside the Contour}$$

$$\Phi(a, b) = 0 \text{at the Contour}$$

$$\Phi(a, b) < 0 \text{Outside the Contour} \qquad (5)$$

By changing the value of ϕ as shown in (5), some regions will turn to positive, that were originally negative and some regions turn to negative that were originally positive. Hence contour will change position according to update value of level set function

E. Identification of stone size and location

Identification of CT kidney stone process depends on the segmentation results. If the level set segmentation algorithm results, it indicates the presence of stone/s if stones are present in the kidney then size of kidney varies by 2cm than its original size.

Algorithm: Identification of kidney stone

Input: Computed tomography images of kidney.

Output: Segmented regions of kidney representing calculi.

Start

Step1: Read the input image from database

Step2: Crop the image by threshold value (pre-processed).

Step3: Fuzzy c-means clustering

Step4: Extracting last cluster

Step5: Add pixels with intensity that is nearer to the mean of a region.

Step6: Level set segmentation output

Step7: Masked stone

Step8: Continue, until all pixels belong to some regions

End

In our proposed work, we are considering region parameter extraction for renal calculi images of kidney. If the segmentation results with regions representing the renal calculi, region parameters are extracted for that renal calculi CT image. Region parameters used are centroid, area, etc.

Centroid: It represents the centre of mass of the kidney. Kidney centroid is detected.

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

III. Experimental Results

Proposed work is implemented in MATLAB image processing platform version R2015b. The performance is evaluated for 50 patient images.

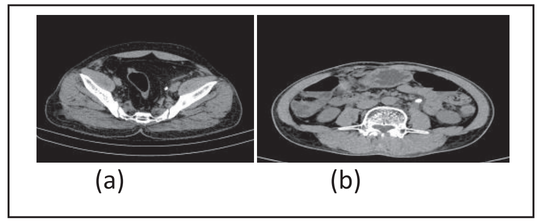

Fig 2.CT scan sample images of kidney stone.

The Fig 2 shows sample CT image renal calculi images. The input images are initially pre processed i.e. images are cropped to enhance the image for easier analysis and accurate segmentation. Fig 3 shows the preprocessed images

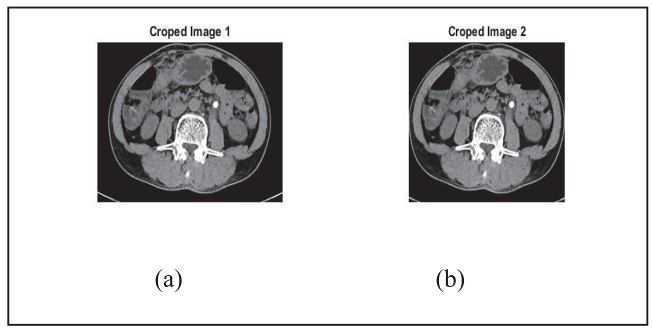

Fig.3 (a) cropped image for y axis (b) cropped image for both x and y axis

In preprocessing, input images are cropped to improve the enhancement of the image for accurate segmentation. Fig.3 (a) show the image is cropped in y axis by calculating the row sum and fig.3 (b) shows column sum of matrix for each x and y axis based on threshold value.

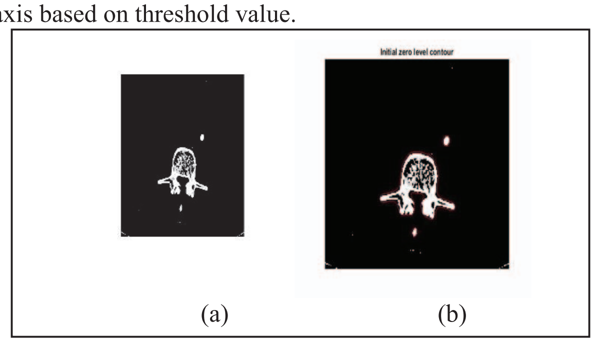

Fig.4 (a) Extracted last cluster (b) Initial zero level contour

Fig.4 (a) shows extraction of the last cluster by using fuzzy c-means clustering and fig.4 (b) shows initial zero level contour after level set segmentation.

(a) (b)

Fig 5 (a) stone area (b) kidney stone detected.

The above fig.5 (a) shows the kidney stone after level set segmentation fig.5 (b) shows the identification of stone area and location of that stone.

Table.1 The area of kidney stones and location of the stones of our proposed work for the single image

Sample images	Table for stone location and area		
	Number of stones	*Total area(in pixel)*	*Location of stone(X,Y)*
Calculi	1	19	149,69
Calculi	1	12	142.08,82.08
Calculi	1	29	96.03,73.72
Calculi	1	23	170.60,96.04

Table.1 contains the information regarding number of kidney stones, area for each stone. In table 1, we have considered one sample calculus image, which has stone area of 19 pixels and stone size of 5.02mm. A sample calculi image has 1 stone and total area of 29 pixels, size of stone is 7.67mm respectively.

IV. CONCLUSION

This work describes a method for identification of renal calculi using level set segmentation. Pre-processing involves the cropped images of kidney. The segmentation results with regions then region properties are extracted for those regions. Size and location required for entire process is calculated for each kidney images. Our proposed method is efficient and the time taken to process the image is lower.

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