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Segmentation of Renal Calculi from CT Abdomen Images by Incorporating FCM and Level Set Approaches

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Abstract: In this paper, CT abdomen images are engaged to the segment kidney stones. The proposed work to perform segmentation of renal calculi is done at two stages. At first stage, the CT abdomen scan image is partitioned into different clusters by spatial fuzzy c means clustering method. From the divided clusters, the kidney region is selected and the fuzzy level set method is applied at the second stage. The proposed work is compared with the threshold and level set method implementation on CT abdomen images. The comparison of the two methods and the efficiency of the proposed work are analyzed quantitatively by using the evaluation parameters; Jaccard similarity coefficient and Accuracy. The qualitative and the quantitative analysis prove that the proposed work gives a proficient segmentation of renal stones from CT abdomen images.

Keywords: Image Segmentation, Kidney Stone, FCM, Level Set, Jaccard, Accuracy.

I. INTRODUCTION

Images are one of the most important medium to deliver information in the field of computer vision. Now there is a need for understanding and extracting images. Image segmentation paves a way for both [1]. Image segmentation is the base of object recognition. It is the first step in image analysis. The purpose of image segmentation is to partition an image into meaningful regions with respect to a particular application. The segmentation is based on measurements taken from the image and might be grey level, color, texture, depth or motion. The goal of segmentation is to simplify or change the representation of an image into something that is more meaningful and easier to analyze.

Image Segmentation techniques are classified based on two properties, discontinuity and similarity. The idea behind the discontinuity principle is to extract regions that differ in properties such as intensity, color, texture, or any other image statistics. The idea behind the similarity principle is to group pixels based on common property [2]. Medical image segmentation is not a task similar to conventional image segmentation. Compared to real time images, medical images differ in many aspects. Hence there is a need that the segmentation of medical images is to be handled critically. The diagnosis of medical abnormalities by physicians depends mostly on the related medical images. Kidney stone is one such problem that affects the regular functions of kidneys and if neglected cause more serious defects in human body. A kidney stone is a hard, crystalline mineral material formed within the kidney or urinary tract. **Nephrolithiasis** is the medical term for kidney stones. "Nephrolithiasis" is derived from the Greek nephros- (kidney) lithos (stone). The stones themselves are also called **RENAL CALCULI**. The word "calculus" (plural: calculi) is the Latin word for pebble [3]. Kidney stones are small masses of salt and minerals that form inside the kidneys and may travel down the urinary tract. Kidney stones range in size from just a speck to as large as a ping pong ball. It is necessary to detect the renal calculi present in kidneys at the earlier stage before the abnormality gets extended. Among the medical imaging modalities such as Ultrasound, MRI, PET, SPECT, this paper concentrates on the CT scan of Abdomen to determine and segment kidney stones. The Computed Tomography of Abdomen gives a maximum detail about the anatomy of kidney when compared to other modalities.

Fig 1: CT Abdomen Scan

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II. FUZZY C MEANS CLUSTERING

The fuzzy c-means clustering algorithm is a variation of the popular k-means clustering algorithm, in which a degree of membership of clusters is incorporated for each data point. The centroids of the clusters are computed based on the degree of memberships as well as data points. The random initialization of memberships of instances used in both traditional fuzzy c-means and k-means algorithms lead to the inability to produce consistent clustering results and often result in undesirable clustering results. This algorithm works by assigning membership to each data point corresponding to each cluster center on the basis of distance between the cluster center and the data point. More the data is near to the cluster center more is its membership towards the particular cluster center [5].
Let x_j (j=1,2,3,….,n) denotes an image with n pixels to be partitioned into c clusters, where x_j represents features data. The clustering process can be defined as

$$J= \sum_{i=1}^{c} \sum_{j=1}^{n} u_{ij}^{m} d_{ij}^{2} \qquad \ldots(1)$$

$$d_{ij} = \left\| c_i - x_j \right\| \qquad \ldots(2)$$

where u_{ij} presents the membership of x_j in the i^{th} cluster, $u_{ij} \in [0,1]$. C_i is the i^{th} cluster centre and m is a constant. The parameter m controls the fuzziness of the resulting partition.
The performance of FCM depends on the initial membership matrix values [4]. FCM clustering techniques are based on fuzzy behavior. They provide a technique which is natural for producing a clustering where membership weights have a natural interpretation but not probabilistic at all.

III. LEVEL SET APPROACH

Level Set Method is one of the emerging image segmentation techniques for medical image segmentation. The level set method is a numerical technique for tracking interfaces and shapes. It was first introduced by Osher and Sethian to capture moving fronts in 1987. The basic idea of the level set method is to represent contours as the zero level set of an implicit function defined in a higher dimension, usually referred to as the level set function, and to evolve the level set function according to a partial differential equation [6].

Osher and Sethian presented level set for front propagation, being applied to models of ocean waves and burning flames. Malladi applied it for medical imaging purposes [7]. The main advantages of the level set method are the relatively fine resolution that can be achieved, the handling of slightly tilted lines and corners, and the precise and easy calculation of surface normals. The standard level set function is defined as

$$\frac{\partial \emptyset}{\partial t} + F|\nabla \emptyset| = 0 \qquad \ldots(3)$$

$$\emptyset\,(0, x, y) = \emptyset_0(x, y) \qquad \ldots(4)$$

where $|\nabla\emptyset|$ denotes the normal direction, $\emptyset_0(x, y)$ is the initial contour and F represents the comprehensive forces. $\emptyset_0(x, y)$ is defined as

$$\emptyset_0(x, y) = \begin{cases} -C_0 & \text{if } (x, y) \text{ is inside } \emptyset_0 \\ C_0 & \text{otherwise} \end{cases} \qquad \ldots(5)$$

Here $C_0 > 0$ is a constant.

IV. PROPOSED WORK

The proposed work is to segment the renal stones from the CT abdomen scan image. For this segmentation process, the input image is divided into groups by using Fuzzy c means clustering. This FCM implementation is done by using weighted spatial membership functions. From the segmented clusters, a single cluster image is chosen depending on the area of the renal stone presence and fuzzy level set method is applied on it for the segmentation of renal calculi. The final output is then compared with the original image by using Jaccard distance as its evaluation parameter.

Compared to medical imaging modalities such as ultrasound, MRI, etc., Computed Tomography (CT) imaging is the best way to detect and diagnose the abnormalities of Kidney such as Renal Stone, Acute renal failure, chronic kidney disease, etc. Hence, CT images are the preferred choice in this work. This proposed method is compared with the implementation of level set method on the traditional thresholded CT abdomen scan image. This comparison proved that the application of fuzzy c means clustering and its advantage of applying it before processing the fuzzy level set method on the input image. The controlling parameters of the level set function are automatically assigned by means of choosing an image from the clusters. This is a major advantage that the manual intervention of value assignment to the controlling parameters is not needed. Hence, this work gives an automated segmentation of renal calculi from CT abdomen images.

The proposed work is executed by two stages. First stage comprises of the partition of image as clusters by using spatial FCM method and in the second stage the fuzzy level set method is implemented on input cluster image.

A. Algorithm
The algorithm of the proposed work is as follows:
Step 1: Input CT Abdomen Image.
Step 2: Apply filter to preprocess the image.
Step 3: Apply the Fuzzy c means clustering method with spatial membership functions and partition the image into distinct clusters.
Step 4: Display the cluster images.
Step 5: Select an input image from the cluster images depending on the region of kidney in the abdominal scan.

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Step 6: Define the initial level set function to be applied on the selected image.
Step 7: Perform the level set evolution for the automatic assignment to values to the controlling parameters of the level set function.
Step 8: Implement the contour on the input image based on the controlling parameters.
Step 9: Extract the contour region.
Step 10: Display the segmented region.

The membership functions of the Fuzzy c means algorithm are made spatial and the value of the controlling parameters of the level set approach is assigned automatically when the input is taken from the fuzzy cluster image. The execution of this algorithm is iterated till the qualitative output is found to be absolute. The final segmented region is then displayed for qualitative analysis and the quantitative results are evaluated then.

B. Data Flow Diagram
The dataflow diagram of the proposed method is presented in Fig 2. The CT abdomen image is received as input and the renal calculi is segmented by implementing fuzzy clustering and level set approach and the segmented image is displayed.

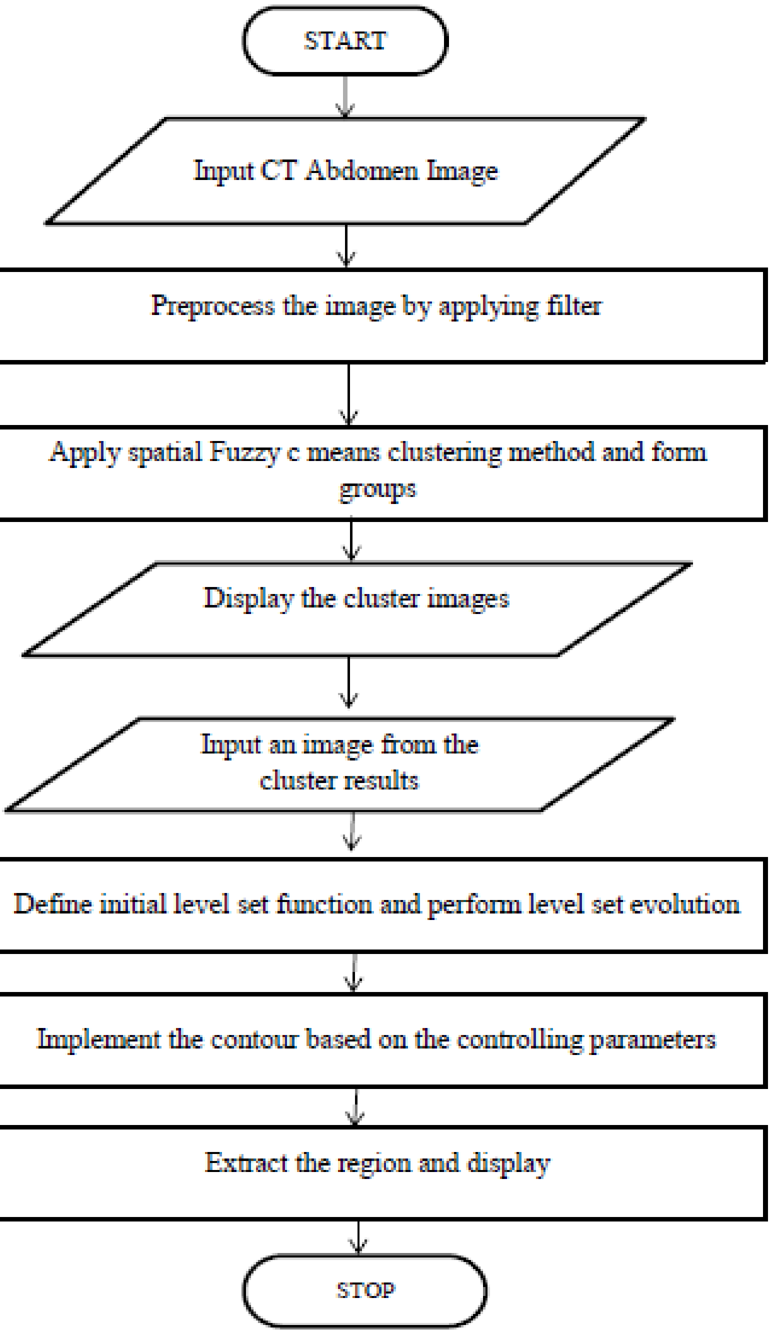

Fig 2: Data flow Diagram of Proposed Work.

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V. RESULTS AND DISCUSSION

The proposed work is implemented on CT Abdomen images and the results are validated here. The qualitative analysis displays the original CT Abdomen images, Fuzzy clustered images, level set applied images and the segmented output images. Fig 3 shows the results of the proposed work.

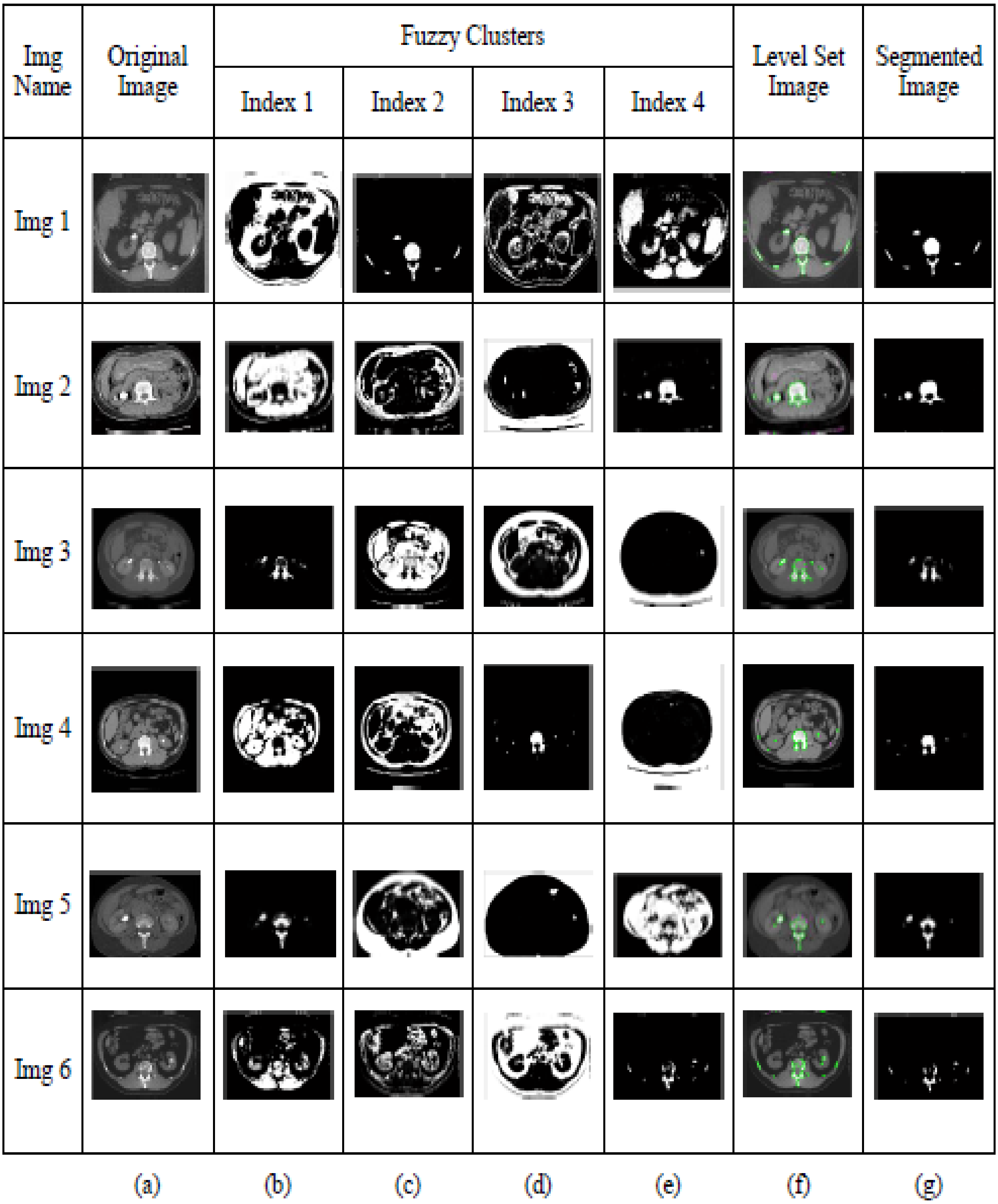

Fig 3: Qualitative analysis of proposed algorithm on different CT abdomen images (a) Original Image (b) – (e) Fuzzy clusters (f) Level Set Approach on selected cluster image (g) Segmented Image.

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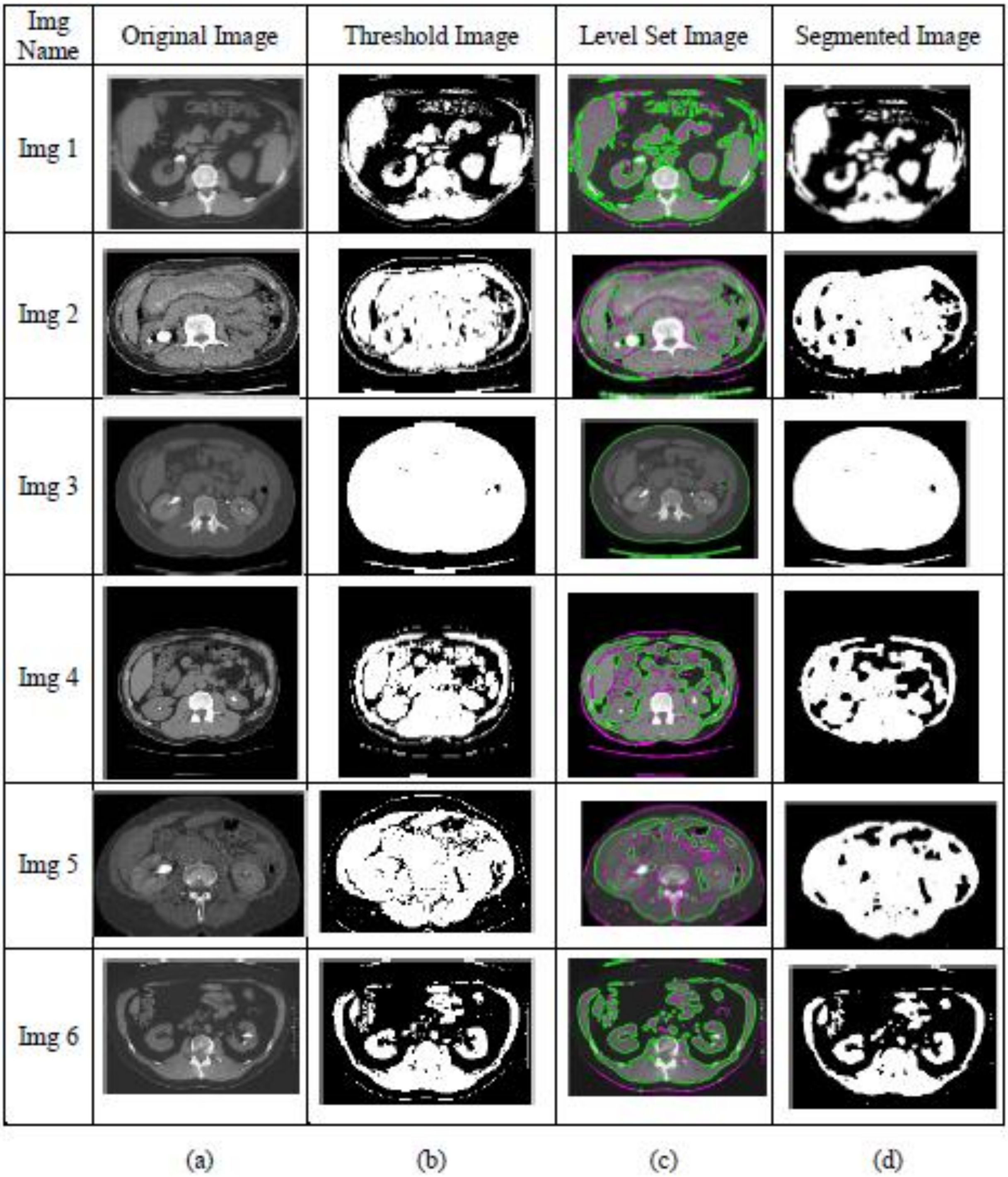

Fig 4: Qualitative analysis of threshold and level set implementation on CT abdomen images. (a) Original Image (b) Threshold implementation (c) Level Set Approach on threshold image (d) Segmented Image.

A. Performance Evaluation

The quantitative analysis of segmentation is done by using Jaccard similarity coefficient and accuracy as evaluation parameters. The jaccard similarity coefficient (J) can be given by

$$J(x, y) = \frac{|x \cap y|}{|x \cup y|} \quad \ldots(3)$$

where x represents the total pixels of the image obtained by the proposed method and y represents the total pixels in the image obtained from ground truth data. Accuracy is a broadly used metrics to evaluate performance of segmentation methods. It is normally used to evaluate the general performance of the proposed method.

Accuracy can be defined as

$$accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad \ldots(4)$$

where TP is the number of true positive cases; TN is true negative cases; FP is false positive cases and FN is false negative cases. The performance comparison of the two methods reveals that the proposed method gives more accurate output than the other one. Table 1 illustrates the jaccard similarity index of two methods and Table 2 proves the accuracy of the proposed method is higher than the other.

Table 1: Comparison of Jaccard similarity Coefficient of Two Methods.

Image Name.	Threshold and Level Set Method	Proposed Method
Img 1	0.5989951	**0.9617729**
Img 2	0.2639636	**0.9259712**
Img 3	0.3237859	**0.9737275**
Img 4	0.6634321	**0.9711121**
Img 5	0.4649857	**0.9596358**
Img 6	0.6864462	**0.9717624**

Table 2: Comparison of Accuracy of Two Methods.

Image Name.	Threshold and Level Set Method	Proposed Method
Img 1	0.5874921	**0.9574236**
Img 2	0.3936831	**0.8931258**
Img 3	0.3259003	**0.9355869**
Img 4	0.6521877	**0.9617778**
Img 5	0.4656995	**0.9092011**
Img 6	0.6756268	**0.9571692**

VI. CONCLUSION

Image segmentation plays a dynamic role in the field of medical image analysis. Fuzzy C means clustering and Level set are two obvious methods used in Image segmentation. In this paper, both of these methods are integrated and used to segment renal stones from CT abdomen images. By implementing fuzzy clustering spatial membership functions, the image is grouped distinctly into several clusters. The fuzzy level set method is then executed on the selected image from the clusters. This proposed method segments the renal stone from the CT abdomen images. The proposed work is compared with the method of implementing level set on threshold image. The segmentation is evaluated using parameters such as Jaccard similarity coefficient and accuracy and the results are discussed. The comparative results proved the proposed method outrivaled the other.

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