IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 21, Issue 5, Ser. I (Sep - Oct 2019), PP 48-54
www.iosrjournals.org

Comparison of Different Segmentation Algorithms on Ultrasound Stoned Kidney Image

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Abstract: *Image segmentation plays a vital role in ultrasound digital image applications, for the study of anatomical structures of medical-image. Image segmentation is a tool for dividing an image into multiple parts, to identify objects or other relevant information in digital images. This paper shows some implementation and comparison of different segmentation algorithms like Edge based segmentation, Watershed segmentation, Region based segmentation, Thresholding and Clustering method which separates stones sections from ultrasound kidney image. This paper is to present which method is performing best for segmentation task. The performance of those segmentation methods are measured by calculating the MSE, PSNR and elapsed time of segmented kidney stoned image.*

Keywords: *Image Segmentation, Objective Evaluation, Edge Detection, Watershed, Thresholding, Clustering;*

Date of Submission: 09-09-2019 Date of acceptance: 25-09-2019

I. Introduction

Image segmentation is one of the most challenging task in image processing and is broadly used in many applications like sports, biomedical, remote sensing satellites, security purposes etc. Segmentation procedures subdivide an image into its constituent parts or objects. It is a process of partitioning a digital image into multiple regions or sets of pixels. This partitioning process should be stopped when the object of interest in an application has been separated [1]. Manual detection of stone from ultrasound kidney image is a time consuming and is also susceptible to errors. Due to large number of patients and scans of ultrasound (US) images, cause large amount of data and detection of stone is cumbersome. So we need some automatic detection process. In automatic detection of stone from ultrasound kidney image, segmentation plays an important role. Many segmentation techniques are exists for the separating objects from image. Those are based on edged based approach, region growing approach, threshold approach, watershed approach, clustering approach etc. In this paper, we compared different segmentation algorithms performance in case of detecting stones from ultrasound kidney image. The segmentation method’s performance is measured by calculating mean square error (MSE), peak signal to noise ratio PSNR and elapsed time of segmented kidney stoned image.
The algorithm of the proposed work is given below:

i. Collecting the ultrasound stoned kidney images.
ii. Preprocessing of acquired image.
iii. Applying different segmentation methods for detecting stones in kidney.
iv. Comparing the results of those segmentation methods
v. Finding the best segmentation algorithm for detecting stones from ultrasound kidney image based on parameters MSE, PSNR, and elapsed time.

II. Noise Removal of Acquired Image

In biomedical image analysis, noise removal plays vital roles. The use of ultrasound imaging in medical diagnosis is well established because of its noninvasive nature, low cost, capability of forming real time imaging and continuous improvement in image quality [2]. During image acquisition, noise is always present in the ultrasound images. Different types of noise-like Gaussian, Salt and Pepper, Poisson and Speckle could be present in the ultrasound kidney stone image during acquisition. Different types of filters like- Median, Averaging/Mean, Gaussian, and Wiener are used for removal of noises [3]. An important property of image de-noising model is that it should completely remove noises with preserving edges. Basically the image quality is measured by the PSNR and MSE [4]. Weiner filter has lowest MSE and highest PSNR for Speckle noise, so this filter gives the best performance on four different types of noise for stoned kidney image [5].
By applying wiener filter, the acquired image has been preprocessed showed in Figure 1.

(a) Original (b) Segmented

Figure 1: Pre-processing of stoned kidney US image

III. Segmentation Methods

Segmentation is a process that partitioned an image into different parts having similar features. Image preprocessing is done initially, followed by segmentation using clustering technique for extraction of stoned section from US kidney image which is our region of interest. Several general purpose algorithms and techniques have been developed for image segmentation in the last few years. As there is no general solution for the image segmentation problem, techniques like Thresholding, Edge based, Clustering, Region Growing, Artificial neural networks etc. are often combined with domain knowledge in order to effectively solve an image segmentation problem [5]. Among those methods, only four methods are used to implement in a kidney image.

A. Edge/Boundary Based Method

In edge based segmentation, the boundary is identified to segment. Edges are detected to identify the discontinuities in the image. Edges on the region are traced by identifying the pixel value and it is compared with the neighboring pixels. An edge based segmentation approach can be used to avoid a bias in the size of the segmented object without using a complex thresholding scheme. Edge-based segmentation is based on the fact that the position of an edge is given by an extreme of the first-order derivative or a zero crossing in the second-order derivative. Edge or boundary based methods attempt to solve the image segmentation by detecting the edge between different regions. The edge method has the advantage that it analyzes the images by drastically reducing the amount of data to be processed, while at the same time preserving useful structural information about object boundaries [6]. For ultrasound images which have inherent speckle noise and texture characteristics, edge detector only algorithms cannot achieve high quality results. Therefore, traditional edge detection method rarely used alone [7]. In [8], it introduced a combination of canny edge detector with gradient vector flow algorithm. By coupling the smoothness of the edge map to the initial size of the snake, enhancing the tumor boundaries, better tumor boundary have obtained. Different from [8], we use canny edge operator with level set function.

B. Threshold Method

Thresholding is one of simple image segmentation technique. It is a process of separating pixels in different classes depending on their pixels gray levels. A Thresholding method determines an intensity value, called the 'threshold', which separates the desired classes. The segmentation is achieved by taking threshold value. Based on the threshold value, pixels are grouped with intensity greater than the threshold into one class and remain pixels grouped into another class. The main disadvantages are that, in the simplest form only two classes are generated and it cannot be applied to multichannel [9] images. In Thresholding technique, images have only two values either black or white. MR image contains 0 to 255 gray values. So, Thresholding of MR images ignore the tumor cells [10]. Segmentation through Thresholding has less computational complexity compared to other techniques [11]. Segmentation is based on 'histon'. From a particular segment, there may be a set of pixels which are termed as 'histon'. Roughness measure is followed by a Thresholding method for image segmentation [12]. Segmentation is done through adaptive thresholding. The gray level points where the gradient is high, is then added to Thresholding surface for segmentation [13]. The drawback of this segmentation technique is that it is not suitable for complex images. From a gray scale image, Thresholding can be used to create binary images. In this method image is segmenting by comparing pixel values with the predefined threshold limit L [14].

The threshold segmentation can be mathematically represented as:

$$I(i,j) = \begin{cases} 0, v(i,j) < L \\ 1, v(i,j) \geq L \end{cases} \quad (1)$$

where v(i, j) is the pixel value at the position (i, j) and I(i, j) is the output image.

The procedure for the threshold segmentation is described as, comparing individual pixels in an image with threshold value and assigns 0 or 1 based on the condition described in Equation 1. This will convert that gray scale image into a binary image. In the threshold segmentation method, threshold is the key parameter. There are different methods to select that threshold value. One is manual selection, which is like a trial and error basis. Simple automatic threshold selection is based on mean or median and histogram. Unimodal threshold selection algorithm is much better to use in medical images, which is relatively simple, does not require much specific knowledge of the image [14].

C. Watershed Segmentation

Watershed segmentation is a way of automatically separating or cutting apart particles that touch. It starts with a mask or binary image, where the particles are (say) black. It calculates a distance map to find the fattest parts of the object (the peaks or local maxima of the distance map). Starting with the peaks as maximal erosion points (MEP's), it dilates them as far as possible - either until the edge of the object is reached, or the edge of the region of another (growing) MEP [15].

D. K-Means Clustering Method

K-means is one of the simplest unsupervised learning algorithms that solve the well-known clustering problem by iterative technique. The procedure follows an easy way to classify a given data set through a certain number of clusters (assume K clusters) fixed a priori. The procedure for K-means clustering algorithm is simple and easy way to segment the image using basic knowledge of cluster value. In K-means initially randomly define K centroids. The selection of this K centroid is placed in cunning way because different location makes different clustering. So, better is to place centroid value will be as much as far away from each other. Secondly, distance calculation between each pixel to selected cluster centroid. Each pixel compares with k clusters centroids and finding distance using distance formula. If the pixel has shortest distance with a centroid among all, than it will move to that particular cluster. Repeat this process until all pixels are compared to the cluster centroids. The process continues until some convergence criteria are met [16]. A basic clustering algorithm i.e. K-means is used for segmentation in textured images. It clusters the related pixels to segment the image [17].

E. Fuzzy C Means Clustering Method

In the year 1973, Dunn developed the Fuzzy C Means algorithm and later in 1981 it was enhanced by Bezdek. However the Fuzzy logic was proposed in 1965 by Lofti A Zadak, a professor of Computer Science at University of California, Berkeley. Fuzzy logic is a form of many valued logic or probabilistic logic. It by definition only means approximate values rather than fixed and exact. In contrast with traditional logic they can have varying values, where binary sets have two-valued logic, true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false.

IV. Performance Parameters

In order to know the efficiency of the above methods we use parameters like Energy, Entropy, Elapsed time, Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE) etc.

A. Elapsed time

Elapsed time is the time that taken to retrieve the segmented area from the input image. This method is calculated by tic and toc methods in MATLAB.

B. Mean Square Error (MSE)

For an image I with m x n dimension, the MSE can be calculated as:

$$MSE = \frac{1}{m\,n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - K(i,j)]^2 \qquad (2)$$

Where I (i, j) and K (i, j) are the input and output image, respectively. The value of MSE should always be less than PSNR. Lower the value of MSE of an image means less error and high quality of the image. PSNR and MSE are inversely proportional to each other.

C. Peak Signal to Noise Ratio (PSNR)

PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the accuracy of its representation.

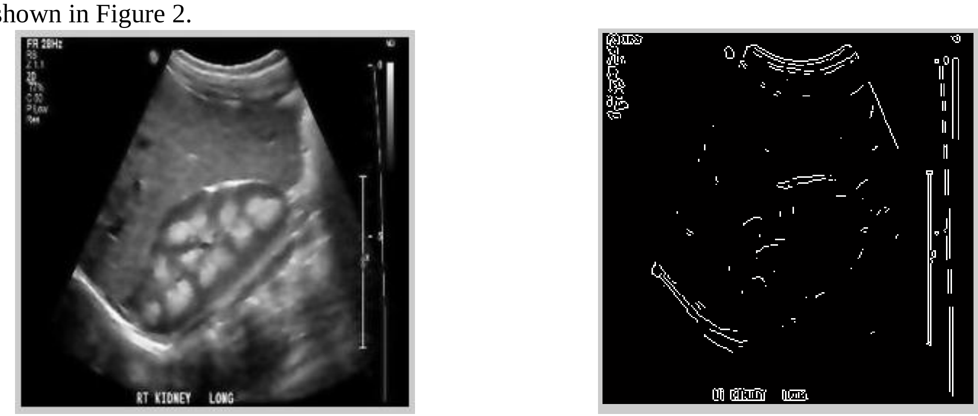
$$\begin{aligned} PSNR &= 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) \\ &= 20 \cdot \log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \\ &= 20 \cdot \log_{10}(MAX_I) - 10 \cdot \log_{10}(MSE) \end{aligned} \quad (3)$$

Higher the PSNR values, better the quality of image. If PSNR value is above 30, that means the output has hundred per cent image clarity. The unit of PSNR is dB (decibel). It takes from 0 to infinity.

V. Results and Analysis

In this paper, we first filtered the acquired kidney stoned image by Weiner filter, then applying different types of segmentation algorithms on it. Then we calculated elapsed time, MSE and PSNR to decide which segmentation technique is best for detecting stone from kidney stoned image. The following figures represent the sample of kidney stoned images after simulating with several segmentation methods.

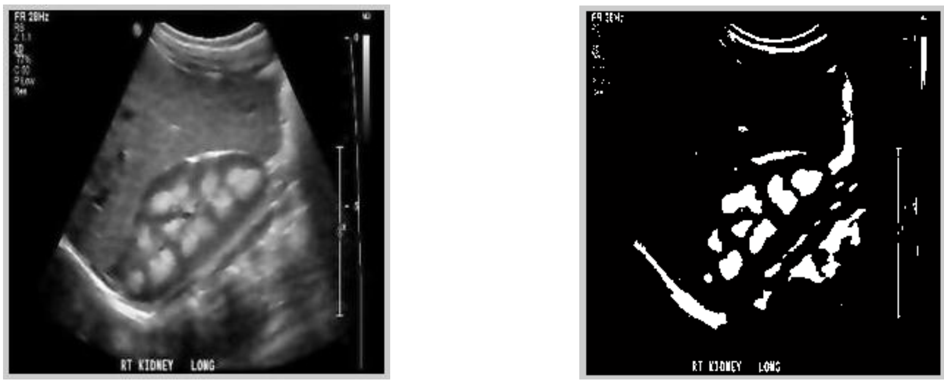
The Simulation is run by MATLAB R2010a. Edge based segmentation is one of the simplest method here where we have used Sobel operator to detect edges. Edge based segmentation for ultrasound (US) kidney image is shown in Figure 2.



(a) Original **(b) Segmented**

Figure 2: Edge based segmentation of the stoned kidney US image

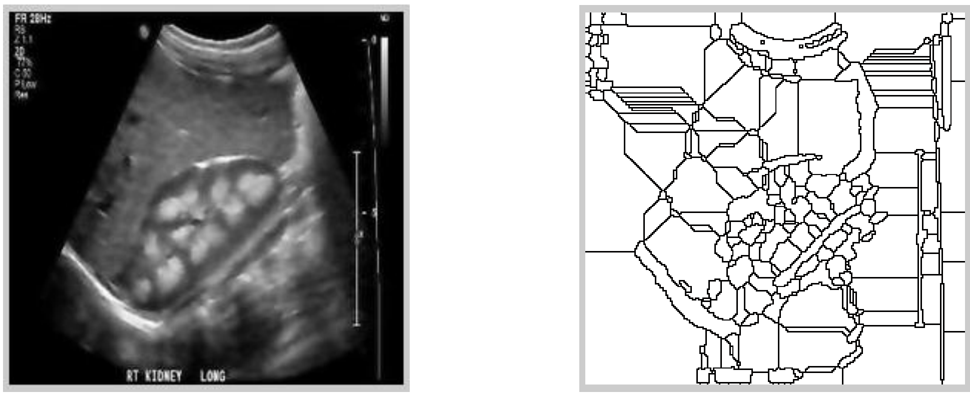
Thresholding is the simplest method of image segmentation. This method is based on a threshold value to turn a gray-scale image into a binary image. Threshold segmentation for US Kidney Image is shown in Figure 3. Appropriate threshold segmentation for the stoned kidney US image is obtained for the threshold value 140 where gray level is considered from 0 to 255. Threshold value is obtained based on trial and error method.



(a) Original **(b) Segmented**

Figure 3: Threshold segmentation of the stoned kidney US image

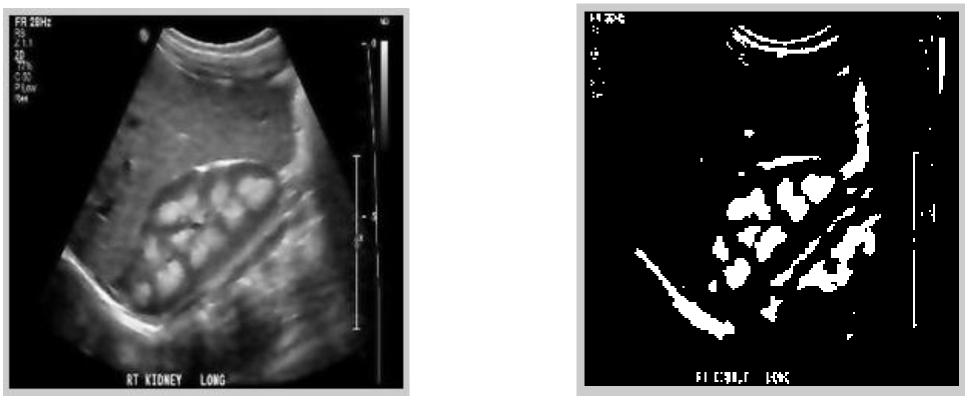
Watershed algorithm is used in image processing primarily for segmentation purposes. The watershed transform finds ‘catchment basins’ and ‘watershed ridge lines’ in an image by treating it as a surface where light pixels are high and dark pixels are low. Watershed segmentation for US kidney image is shown in Figure 4.



(a) Original **(b) Segmented**

Figure 4: Watershed segmentation of the stoned kidney US image

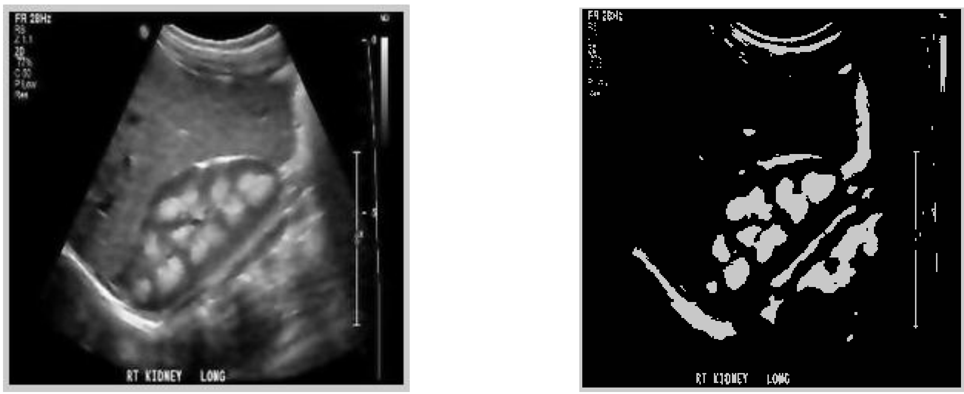
Here K means and Fuzzy C-means algorithm is implemented. There are missing of more number of pixels in the clustering, when compared to the Threshold method and the Watershed and Edge based method. Clustering segmentation for the US Kidney Image is shown in Figure 5.



(a) Original **(b) Segmented**

Figure 5: K means segmentation of the stoned kidney US image

Missing of pixels is due to the noise interference and this lead to the holes in the segmented image. It clearly indicates the stone or abnormal part in the kidney US and it satisfying the clinical validations like utility, improved diagnosis and patient management. Clustering segmentation for the US kidney image is shown in Figure 6.



(a) Original **(b) Segmented**

Figure 6: Fuzzy C-Means (FCM) Clustering segmentation of the stoned kidney US image

Parameters obtained for the various segmentation methods for US kidney image is shown in Table 1.

Table 1: Performance of Segmentation Techniques

Segmentation	**MSE**	**PSNR**	**Elapsed time(s)**
Edged based	5799.12	10.49	1.39
Thresholding	5778.15	10.51	0.60
Watershed	37538.64	2.38	1.24
K-means	5575.13	10.66	1.94
Fuzzy c-means	3271.53	12.98	1.89

Performance comparison for different segmentation methods are shown in Chart 1, 2 and 3.

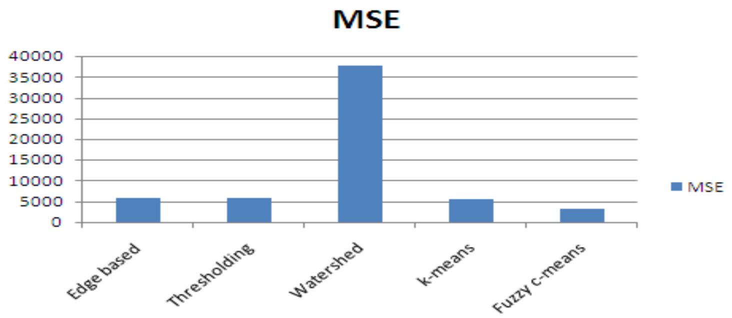


Chart 1: MSE Performance Evaluation for Stoned Kidney Image

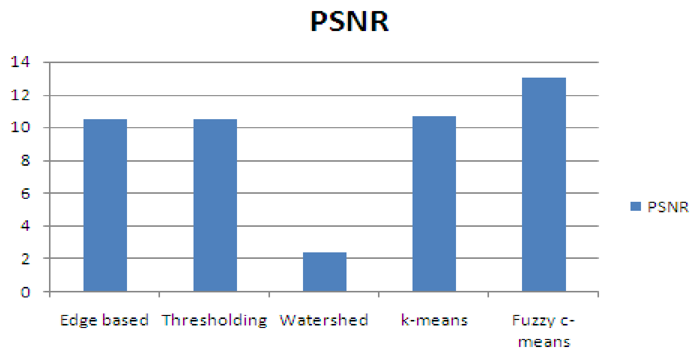


Chart 2: PSNR Performance Evaluation for Stoned Kidney Image

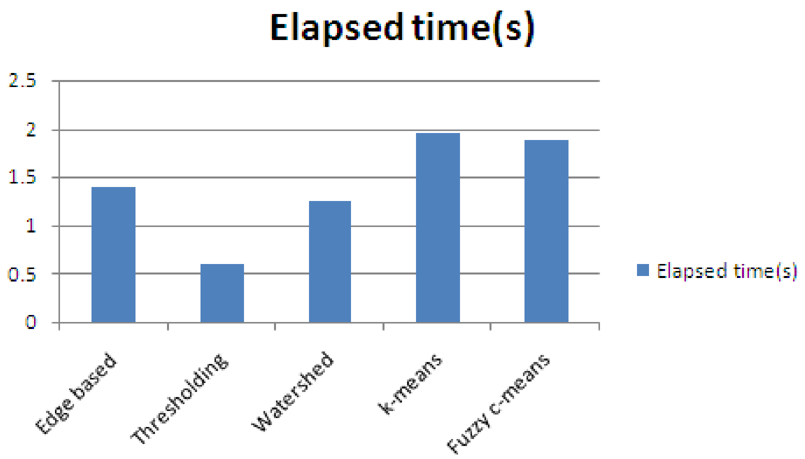


Chart 3: Elapsed Time Performance Evaluation for Stoned Kidney Image

From Table 1, in image segmentation the above comparisons show the qualitative result parameters when compared to various methods. When the PSNR values are high and MSE values are low, the segmentation process gives good results. Elapsed time gives us how much time it takes for a segmentation method to generate the output. Less elapsed time is always preferable for real-world applications. The elapsed time can varies based on the systems computational power, that's why we can consider PSNR and MSE value in case of evaluating segmentation methods. After comparing the PSNR and MSE of all the considered methods, it can be easily say that fuzzy c-means and k-means method gives us most suitable results. Because Fuzzy c-means has highest PSNR and Lowest MSE but has high elapsed time than the K-means method. The Fuzzy c-means method gives best result for kidney stone detection.

VI. Conclusion

From the comparative study it is observed that Fuzzy C means segmentation method is an efficient method for kidney stone detection when compared to other methods. This method offers highest PSNR and Lowest MSE but has high elapsed time than the k-means method. The experiments and results show that Fuzzy C means segmentation method not only reduces the complexity of kidney stone detection, also it improves the classification accuracy. Clustering method in intensity based clustering methods especially Fuzzy c-means and K-means clustering method gives the best segmentation, because the intensity variations in the ultrasound kidney image will be less. So the clustering process will become very easy and it is straightforward for classification and easy for implementation. Intensity variations in the ultrasound kidney image will be less, so the Fuzzy c-means clustering process is highly efficient in ultrasound kidney image segmentation, to compare the features of abnormal and normal medical images and evaluating the significance of the results. So considering the above described parameters we can take Fuzzy C-Means as best segmentation method for kidney stone detection. In Future, we will take other segmentation methods to evaluate the performance in case of kidney stone detection.

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Pronab Kumar Mondal" Comparison of Different Segmentation Algorithms on Ultrasound Stoned Kidney Image" IOSR Journal of Computer Engineering (IOSR-JCE) 21.5 (2019): 48-54