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Automated Methods to Segment Kidneys and Detect Tumors Using CT Images

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Abstract

Kidney tumors are of different types having different characteristics and also remain challenging in the field of biomedicine. It becomes very important to detect the tumor and classify it at the early stage so that appropriate treatment can be planned. The main objective of this research is to use the Computer-Aided Diagnosis (CAD) algorithms to help the early detection of kidney tumors. In this paper, tried to implement an automated segmentation methods of gray level CT images is used to provide information such as anatomical structure and identifying the Region of Interest (ROI) i.e. locate tumor, lesion and other in kidney.

A CT image has inhomogeneity, noise which affects the continuity and accuracy of the images segmentation. In order to obtain good accuracy; the noise must be removed from the input image. Those propose method is started with pre-processing of the kidney CT image to enhance its contrast and removing the undesired noise in order to make the image suitable for further processing. In our proposed work, we have proposed a hybrid filter as a combination of adaptive median and Gaussian HP filter for noise removal and image enhancement. The segmentation process is performed by using the Fuzzy C-Means (FCM) clustering and Watershed methods to detect and segment kidney CT images for the kidney region .The resulted segmented kidney CT images, and then used to extract the tumor region from kidney image.

Keywords: Image segmentation, CT image, Fuzzy C-Means (FCM), Watershed Transform.

طرق آلية لتقسيم الكلى والكشف عن ألاورام باستخدام الصور المقطعية

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الخلاصة

أن اورام الكلى تتكون من عدة انواع مختلفه وأن خصائصها مختلفه بالاضافه الى ان معالجتها مختلفة ،ان كشف الورم وازالته يعتبر من المشاكل الطبية التي تبقى من التحديات التي تواجه حقل الطب البايلوجي ، وأصبح من المهم الكشف عن الاورام وتصنيفها في المراحل الاولية كي يتم التخطيط للعلاج المناسب وان

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الهدف الرئيسي لهذا البحث هو استخدام خوارزميات معينة لتساعد الكشف على اورام الكلية ، في هذا البحث طبقنا طرق التجزئه الالية لصور المستوى الرمادي وهي صور المفراس الحلزوني (CT) التي استخدمت لتزويدنا بمعلومات مثل التركيب التشريحي وتحديد مناطق الاهتمام (ROI) على سبيل المثال تحديد الورم.

ان صور المفراس (CT) فيها ضوضاء متجانسة والتي تؤثر على استمرارية ودقة تجزئة الصور المدخلة . هذه الطرق المقدمة بدأت بمعالجة مسبقه لصور الـ CT للكلية لتحسين التباين وازالة الضوضاء الغير مرغوب فيها من اجل تحسين الصور والحصول على معالجة ادق في هذا العمل تم استخدام طريقة الـ (Mask لعزل الكلى وحدها عن باقي اجزاء البطن) وتعتبر هذه الطريقة مهمه للتخلص من الضوضاء الغير مرغوب بها وبالتالي الحصول على تحسين للصوره وبالتي يمكن ان ان نجري عليها العديد من العمليات مثل التجزئه وعزل الورم وغيرها، بالاضافة الى استخدام مرشحات الوسيط وكذلك مرشح الكاوس قبل عملية التجزئة في هذا البحث تم استخدام خوارمية معدل التضبيب المسماة بالـ Fuzzy C-Mean (FCM) وخوارمية الحد الفاصل المسماة بالـ (Watershed methods) لكشف وتجزئة صور الكلية وأستخراج مناطق الورم فيها .

1. Introduction

Image segmentation is the process of partitioning a digital image into multiple segments or set of pixels. The objective of image segmentation is to group pixels into a prominent image region. Medical Image segmentation is one of most important issues in medical technology, which assists physicians in various aspects, such as analysis and diagnosis of different diseases, the study of anatomical structure, making treatment planning. It refers to the process of deriving meaningful regions from medical images that are homogeneous with respect to local image features such as edges, texture, and color, etc. With the increase of CT images in the diagnosis and treatment of diseases, segmentation of human organs from CT images is a prerequisite step in the precise treatment planning [1].

The segmentation of organs like the liver, pancreas, and kidneys on abdominal computed tomography (CT) scans can form an input to computer aided diagnosis (CAD) systems and laparoscopic surgery assistance. However, different tissues has different sizes and shapes across individuals and the gray scale similarity between kidney and its neighboring tissues, such as liver and spleen. Accurate kidney segmentation in abdominal computed tomography (CT) sequences is an essential and crucial task for surgical planning and navigation in kidney tumor ablation. However, kidney segmentation in CT is a substantially challenging work because the intensity values of kidney parenchyma are similar to those of adjacent structures. Many different methods have been studied over the recent years for segmentation of structures or organs of interest. The commonly-used methods include deformable model, clustering-based method, region growing, statistical shape models, knowledge-based and level set segmentations[2][3].

Several papers in the literature tackle the problem of kidney segmentation in CT images. In [4] the authors used the Active Shape Model framework to learn the kidney mean shape and principal modes of variation, in order to constrain the segmentation. Recently Khalifa et al. [5] proposed a level-set approach, based on a new force combining shape and intensity priors as well as spatial interactions, which showed promising results. All these algorithms are either based on a manual initialization, or tested on images already cropped around the kidney. A fully automatic method has already been introduced by Tsagaan et al. [6], but their detection of the region of interest presents limitations. First, it relies on hard geometrical constraints, which requires knowledge on the field of view. Then, a rough search is done by template matching, which is not robust to pathologies or kidney orientation.

In this paper, tried to implement an automated segmentation methods of gray level CT images is used to provide information such as anatomical structure and identifying the Region of Interest (ROI) i.e. locate tumor, lesion and other in kidney are proposed. In our proposed work, we are using image segmentation technique based on the fuzzy C-Means algorithm (FCM) and watershed method for kidney segmentation to segment the kidney region. The Fuzzy C-Means (FCM) clustering algorithm generalizes the hard C-mean algorithm to allow a point to partially belong to multiple clusters. Therefore, it produces a soft partition for a given dataset. In fact, it produces a constrained soft partition. Watershed transform is a powerful tool for image segmentation; it is a region based approach of segmentation [3]. Watershed transform has many advantages: it is a simple intuitive method, it is always provides closed contours, that is very important in image segmentation, it is fast i.e. it requires low computation times in comparison with other segmentation methods and it produces a complete division of the image in separated regions even if the contrast is poor. The watershed transform has been widely used in many fields of image processing; one of them is medical image segmentation [7].

The remainder of this paper is organized as follows. In section 2, analyze the characteristics of kidney tumors. Image analysis system including ; *Image acquisition* in first stage, *Pre-processing* in the next stage then *image segmentation* of kidney CT image based on the fuzzy C-Means (FCM) and watershed algorithms in third stage are introduced in section 3. The kidney region has been segmented using the algorithm of the proposed method and results are given in section 4, this paper is concluded in section 5

2. Kidney Tumors

The kidneys are a pair of bean-shaped organs, each about the size of a fist. They are attached to the upper back wall of the abdomen. One kidney is just to the left and the other just to the right of the backbone. The lower rib cage protects the kidneys. Small glands called adrenal glands sit above each of the kidneys. Each kidney and adrenal gland is surrounded by fat and a thin, fibrous layer known as Gerota's fascia. The kidneys' main job is to filter the blood coming in from the renal arteries to remove excess water, salt, and waste products. These substances become urine. Urine leaves the kidneys through long slender tubes called ureters, which connect to the bladder. The place where the ureter meets the kidney is called the renal pelvis. The urine is then stored in the bladder until you urinate (pee) [8]. The urinary system and anterior view of urinary organs as show in Figure-1.

Human body consists of myriad number of cells. For a body to remain healthy, cells grow and divide in orderly fashion. When cell growth becomes uncontrollable the extra mass of cell transforms into tumor. Tumor/ Cancer are the abnormal growth of cells or tissues in the organ. Both benign and malignant tumors occur in the kidney. Benign tumors are non-cancerous. Most are asymptomatic, are discovered incidentally, and are not immediately life threatening. Malignant tumors on the other hand, are of great importance clinically and deserve considerable emphasis. By far the most common of these malignant tumors is renal cell carcinoma, followed by Wilms tumor, which is found in children and finally urothelial tumors of the calyces and pelvis. Kidney tumors are known as renal cell carcinoma which includes three main classifications; Chromophobe renal cell carcinoma, renal cell clear cell carcinoma and papillary renal cell carcinoma [3].

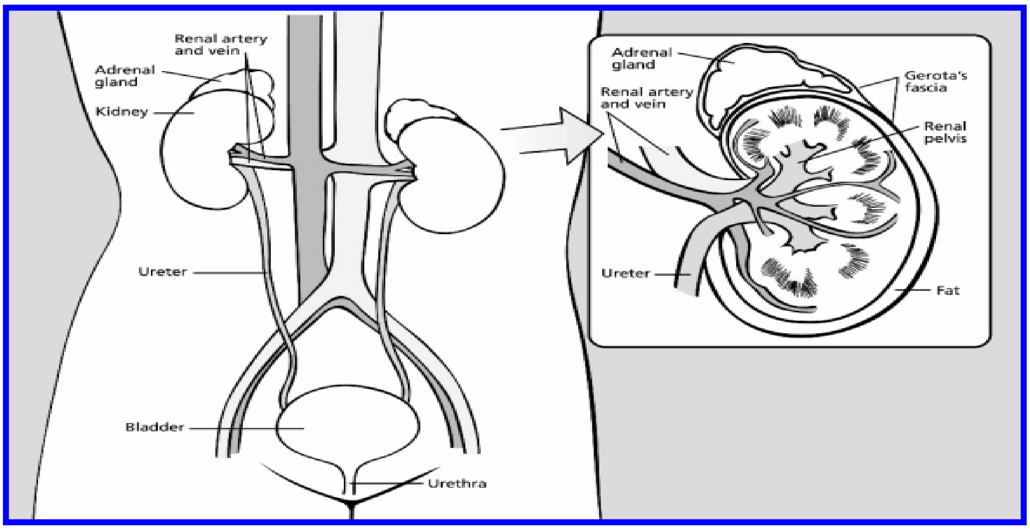

Figure 1- The urinary system and anterior view of urinary organs [8].

3. Image Analysis System

In our proposed work for automated methods to segment kidneys and detect tumors on Computed Tomography (CT) modality for different samples and perform feature extraction consists of 4 steps. The computer imaging Analysis system followed is shown in the block diagram of the basic processes in Figure- 2 includes; Image acquisition in first stage, Pre-processing in the next stage then image, Segmentation in third stage and finally tumor region extraction stage as descript in bellow

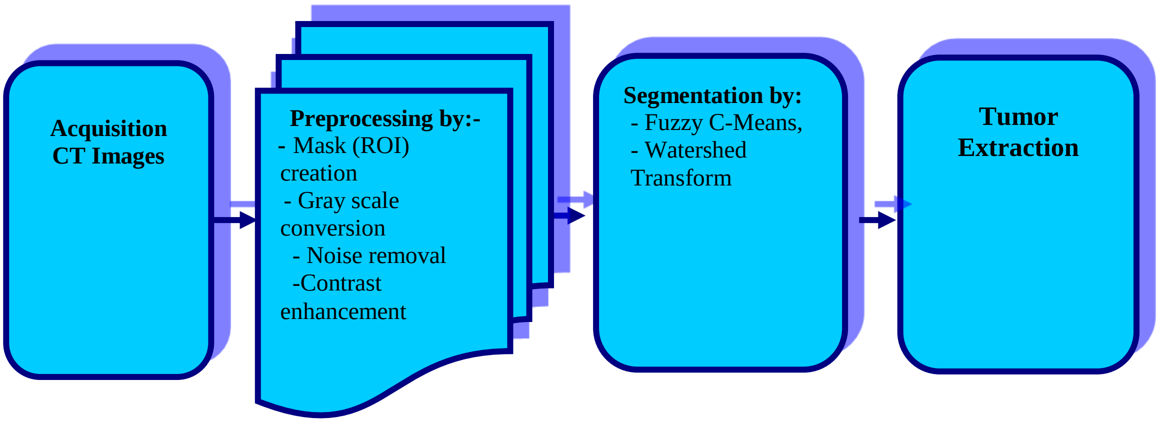

Figure 2- The block diagram of the basic processes.

The medical data used for algorithm evaluation consists of 2D abdominal CT data from different healthy and unhealthy patients of mixed gender (Men, Women) and age (25 to 55 years old). In our proposed work in this research was implemented and performed only one malignant case. The data was acquired using SIEMENS CT scanners Sensation 16 with a resolution in x/y/z from 0.6/0.6/5 to 0.75/0.75/5 (in mm) and provided in DICOM format. The parameters of kidney CT images for scanning were 120.0 KV and 297.0 mA. The pixel spacing was 0.683594 mm, the slice thickness was 1.0 mm and the spacing between slices was 0.3 mm. The number of slices ranged from 65 to 320. Each slice of these datasets had a spatial resolution of 512×512 pixels. CT images of the kidney are processed for the detection of tumor using MATLAB. The block diagram in Figure- 2 shows the overall processing technique. The segmentation experiments and performance evaluation were carried of kidney CT images were run on the 64-bit on the computer with Pentium Intel (R)–Core(TM) i5, CPU (2.5GHz) and 3GB memory. Here, it is worth mentioning that the datasets of Kidney CT images in this project were acquired from Local Hospitals (i.e. Abi Greabe Hospital).

3.2 Pre-processing Stage:

The segmentation of the pre-processed image essentially affects the overall performance of any automated image analysis system. Image regions, homogeneous with respect to some usually textural or color measure, which result from a segmentation algorithm are analyses in subsequent steps. In this part of the work, firstly separate the kidney region from the abdomen CT Images. as inhomogeneity, noise which affects the continuity and accuracy of the images segmentation. Therefore, the first stage in any recognition system is pre-processing. Image pre-processing is the name for operations on images at the lowest level of abstraction whose aim is an improvement of the image data that remove undesired distortions or enhances some image features important for further processing. So, the goal of pre-processing is to remove the noise and to provide contrast enhancement to improve the image quality. The functions performed by pre-processing process are; [9][10].

- Mask Region of Interest (ROI) creation
- Gray scale conversion
- Noise removal
- Contrast enhancement

Mask ROI Creation

In order separate the kidney from the abdomen CT Image it's important to create a mask which is a binary image (0 or 1's). This mask is used to subtract the unwanted features in the images Figure- 3, shows a sample of the mask. The kidney appears white which the value of (1) is and the background which is the reaming information appears (0). This mask which has the size of the kidney and its value and shape differ from one image to another is applied on the original abdomen CT image to discard the irrelevant information multiplying the mask image with study image it produced the masked image which is the kidney image.

Figure 3- shows the mask creation performed to crop the left kidney region.

Conversion to Gray Scale

A grayscale image only consists of gray scale values, but CT images consist of primary colors (RGB) content. A 'Gray' color is one in which the red, green and blue components all have equal intensity in RGB space and so it is only necessary to specify a single intensity value for each pixel, as opposed to the three intensity values needed to be specified for each pixel in a full color image. When CT images are viewed, they look like black and white but they contain some primary colors (RGB) [4]. So, for further processing of CT kidney image, it must be converted to perfect grayscale image, as show in Figure- 4.

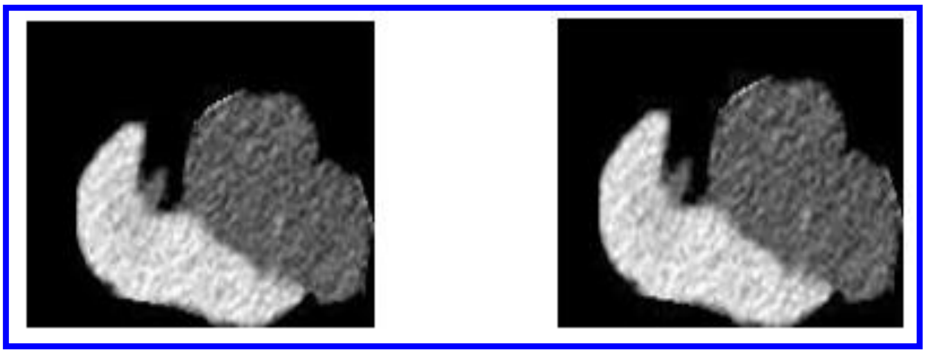

Figure 4- Conversion from RGB to grayscale image.

Noise Removal and Contrast Enhancement

The common noises present in a Renal, Ureter, and Bladder CT Scan are salt & pepper noise, speckles, Gaussian and impulse noises [11]. The order filter that provides median values of the pixels are used because the mean values obtained using averaging filters results in blurring of the image. In CT image, salt and pepper noise and Gaussian are more predominant. We apply non-linear median filter to remove the salt and pepper noise, whereas Gaussian noise is eliminated by a Gaussian high pass filter. The median filter is used to reduce the salt and pepper noise present due to motion artifacts (i.e. Movement of patient during scan) in the CT images. It is done for smoothening of CT image. Here we are using CT median filters to eliminate salt and pepper noise. A high pass filter preserves the high frequency information within an image while reducing the low frequency information, thus emphasizing the transitions in the image intensities.

3.3 Image Segmentation

In this section, the proposed kidney segmentation methods with a hierarchical strategy will be presented in detail. The FCM and watershed transform method was implemented to detect and extract tumors and abnormalities in CT scan kidney images.

A. Fuzzy C-Means (FCM) Clustering Algorithm

The fuzzy logic is used to process data by giving the partial membership value to each pixel in the image. The membership value of the fuzzy set ranges between 0 and 1. Clustering method is a kind of unsupervised learning. So the segmentation methods based on it do not need training sample data, they form clusters of data by grouping pixels. Fuzzy clustering is a multi valued logic system that uses intermediate values i.e., member of one fuzzy set can also be member of another fuzzy set while in the same image. There are no discontinuous or sudden transitions between full membership and non-membership functions. The membership function defines the fuzziness of an image and the information contained in the image. The primary features involved in characterization using a membership function are: core, support, and boundary. The core is completely a member of the fuzzy set. The support is non membership value of the set and boundary is the partial membership value, having its value between 0 and 1. 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. Hence, addition of membership of each and every data point must be equal to one [12].

The idea of fuzzy connectedness goes back to the work of Rosenfeld [3]. Thus improvement in segmentation and tumor detection can be done with fuzzy c-means clustering method. Fuzzy c-means (FCM) clustering is an unsupervised technique that has been successfully applied to feature analysis, clustering, and classifier designs in fields such as astronomy, geology, medical imaging, target recognition, and image segmentation. An image can be represented in various feature spaces, and the FCM algorithm classifies the image by grouping similar data points in the feature space into clusters. This clustering is achieved by iteratively minimizing a cost function that is dependent on the distance of the pixels to the cluster centers in the feature domain. The pixels on an image are highly correlated, i.e. the pixels in the immediate neighborhood possess nearly the same feature data. Therefore, the spatial relationship of neighboring pixels is an important characteristic that can be of great aid in imaging segmentation. General boundary detection techniques have taken advantage of this spatial information for image segmentation. However, the conventional FCM algorithm does not fully utilize this spatial information. So improvement in conventional method can be done by incorporating noise reduction method also. The algorithm is an iterative optimization that minimizes the cost function defined as follows [3]:

Mathematical Representation

Algorithmic steps for Fuzzy c-means clustering:

Let $X = \{x_1, x_2, x_3 ..., x_n\}$ be the set of data points and $V = \{v_1, v_2, v_3 ..., v_c\}$ be the set of centers.

1) Randomly select 'c ' cluster centers.

2) calculate the fuzzy membership 'μ_{ij}' using:

$$\mu_{ij} = 1 / \sum_{k=1}^{c} (d_{ij} / d_{ik})^{(2/m-1)} \tag{1}$$

3) compute the fuzzy centers ' v_j' using:

$$v_j = (\sum_{i=1}^{n} (\mu_{ij})^m x_i) / (\sum_{i=1}^{n} (\mu_{ij})^m), \forall j = 1, 2, ...c \tag{2}$$

4) Repeat step 2) and 3) until the minimum 'J ' value is achieved or

$\|U(k+1) - U(k)\| < \beta$. Where,

k is the iteration step.

β is the termination criterion between [0, 1].

$U = (\mu_{ij})$ n*c is the fuzzy membership matrix.

J is the objective function.

Implementation of the *FCM* segmentation can be done using the following algorithm:

Step 1: *Read the kidney CT image after* kidney *region extracted.*
Step 2: *Input the number of clusters, fuzziness factor and number of iteration (default 100).*
Step 3: *Randomly select the initial centroid of clusters.*
Step 4: *Calculate the Euclidean distance between each pixel and centroid by:* $d = \|x_i - \theta_j\|$*; then find the membership function according to equation (2).*
Step 5: *Find an object function according to equation (1).*
Step 6: *Compare between calculated object function according to above equation for two iterations. Stop if there is no change in membership function or cluster centers at two successive iterations. Otherwise go to Step 4 to update the membership values and cluster centroid.*
Step 7: *FCM method groups elements of the clusters to suitable cluster so that the distance between the element and its corresponding cluster center is minimum.*
Step 8: *Display the output image by find the index matrix for the maximum probability of each pixel have the same position in all clusters.*

b. Watershed Segmentation Algorithm

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 [4]. Briefly speaking, watershed in geography is a ridge that divides areas drained by different river systems. The geographical area draining into a river or reservoir is called a catchment basin. The watershed transforms implements these ideas on gray scale image processing to help solving a variety problems of image segmentation. The concept of this method is based on visualizing an image in three dimensions: two of them represent the spatial coordinates and the third is the gray levels.

Watershed transform can be implemented by applying flooding process. This flooding process can be achieved by using basic morphological operations. The algorithm of watershed transform is based on the concept of "immersion". In this algorithm, each local minimum of a gray scale image, which can be regarded as a surface, has a hole and the surface is immersed out into water. Then, starting from the minima of the lowest intensity value, the water will progressively fill up different catchment basins of the image (surface). Conceptually, the algorithm then builds a dam to avoid a situation that the water coming from two or more different local minima to be merged. At the end of this immersion process, each local minimum is totally enclosed by dams corresponding to watersheds of the image (surface) [13].There are three main methods of implementing watershed transform, which are: Distance transforms approach, Gradient method and Marker controlled approach, for details see [14]. The Marker-controlled approach method of applying watershed algorithm is implemented in this work, and the details are presented in [15].

Implementation of the Marker-controlled watershed segmentation can be done using the following algorithm

Step1*: Read the color image and transform it to grayscale.*
Step2*: Use the Marker-controlled watershed as the segmentation function.*
Step3: Mark the foreground objects.
Step4*: Compute the opening-by-reconstruction.*
Step5*: Following the opening with a closing can remove the dark spots opening and closing are more effective than standard opening and closing at removing small defects without affecting the overall shapes of the objects.*
Step6*: Calculate the regional maxima to obtain good foreground markers.*
Step7*: Compute Background Markers the dark pixels belong to background, so the thresholding operation is needed.*
Step 8*: Compute the watershed transform of the modified segmentation function.*

3.4 Tumor Region Extraction

After the segmentation is performed on kidney region, extracted that can be used as diagnostic indicators. The kidney and tumor regions are separately segmented from the CT images. The operation of tumor extraction from the result classes of Fuzzy C-Means methods can be summarized by the following steps:

Step 1*: Apply* Fuzzy C-means *clustering method on kidney CT images in which the tumor appears.*
Step 2*: Binaries* Fuzzy *C-Means class image that contain tumor with threshold 0.7 or 0.9 (depend on the image).*
Step 3*: open image to remove small objects that have fewer than P pixels (P depend on the tumor and object size), producing another binary image. The default connectivity is 8 for two dimensions.*
Step 4*: Repeat steps 2-3 for all samples,*
Step 5*: Extract only the object that has the area of tumor (depend on the sample) and eliminate other objects.*

The same operation of tumor extraction from the result classes of FCM methods can be used for Watershed method.

4. The Results

The results of kidney segmentation, in patient's CT slice images are presented and discussed in this section. In our proposed work in this research was implemented and performed only one malignant case. The number of slices in selected case ranged 56 slices. The abnormalities in the selected case appear from slice number 4 to slice number 47.

The segmentation of the pre-processed image essentially affects the overall performance of any automated image analysis system. The pre-processing technique involves identifying the main source of noises and removing the noise with a proper filtering technique .In the pre-processing stage, in order to obtain good accuracy, the noise must be removed from the input image we are using median filter and Gaussian high pass filter to remove speckle noise . The common noises present in a Renal, Ureter, and Bladder CT scan are salt & pepper noise, speckles, Gaussian and impulse noises. We have proposed a hybrid filter as a combination of adaptive median and Gaussian HP filter for noise removal and image enhancement. Filtering is a technique used for removing the noise present in an image as shown in Figure-5, mid show the image after applied median filter, right show the image after applied median and Gaussian HP filter.

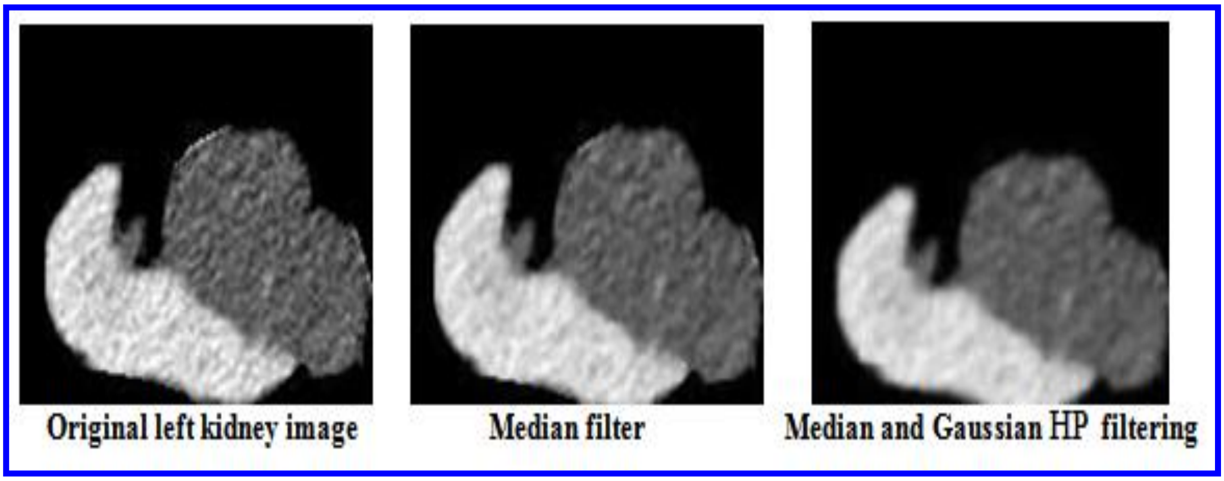

Figure 5- Pre-processing technique after applied median and Gaussian HP filter.

In the segmentation stage, FCM and watershed segmentation algorithm are used to detect and segment kidney CT images. Figures-6 show result after applied FCM clustering algorithm for one sample with 5 classes, the tumor appears in class1. The kidney tumor regions are separately segmented from the image as shown in Figures- (7, 8) show the result after applied watershed segmentation method.

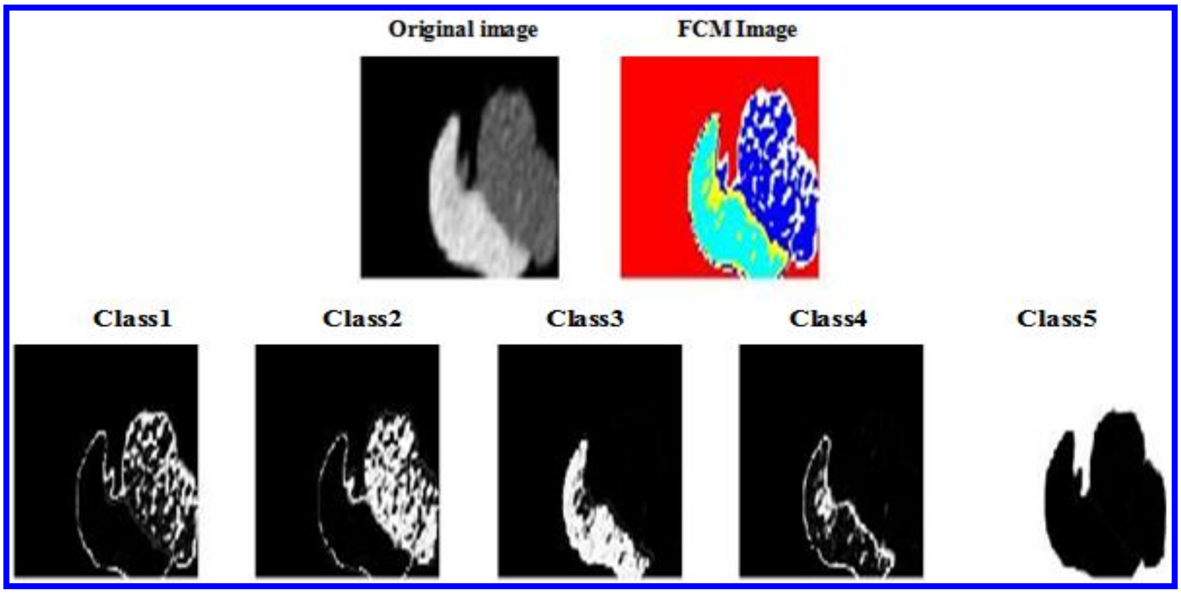

Figure 7- FCM clustering for malignant image with 5 classes, the tumor appears in class1.

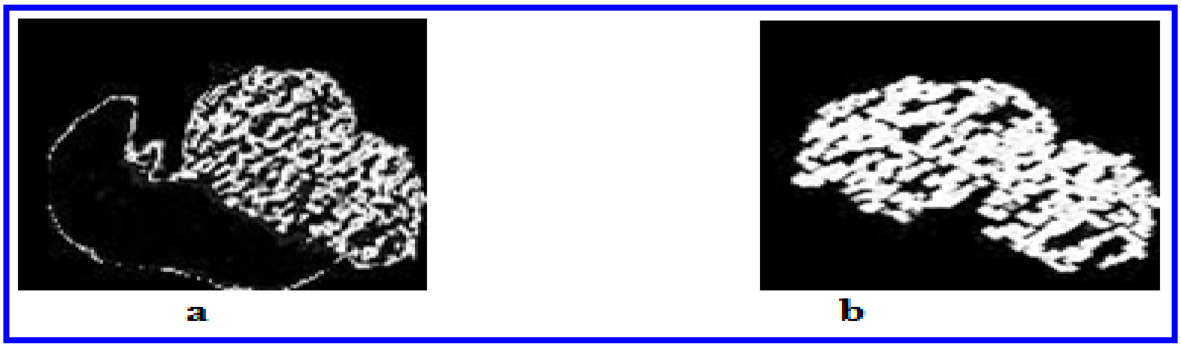

Figure 8- a) Class 1 of FCM include tumor b) extracted tumor.

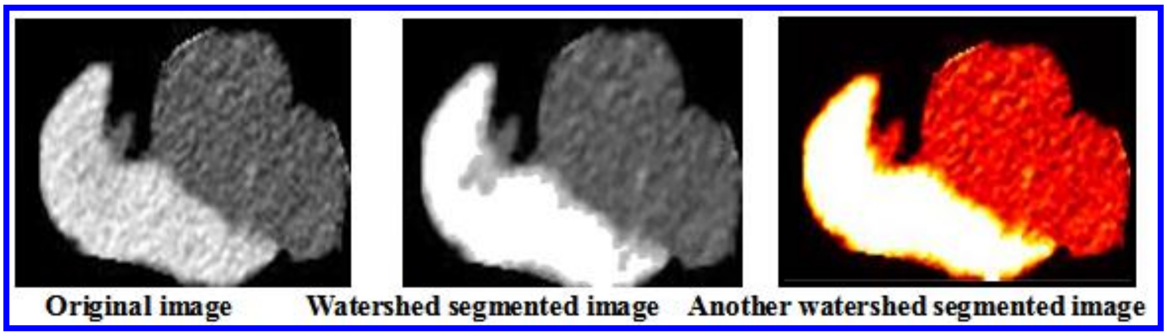

Figure 8-Watershed segmentation for malignant image.

5. Conclusions

The first step in tumor detection is to segment out the kidney portion from the abdominal CT image. This was done with an automated segmentation method. The strength of the automatic segmentation method is general nature which allows it to be applied robustly to multiple organs without specialization and individual parameter settings. This study shows that automated segmentation method will reduce errors occurring while doing manual segmentation. Experimental results were obtained by using MATLAB.

In this paper, an automatic segmentation algorithm for kidney tumor detection and extraction is presented. This paper addresses the problem of segmenting a kidney region from CT images. In the pre-processing stage In CT image, salt and pepper noise and Gaussian are more predominant. We apply non-linear median filter to remove the salt and pepper noise, whereas Gaussian noise is eliminated by a Gaussian high pass filter. The median filter is used to reduce the salt and pepper noise present due to motion artifacts (i.e. Movement of patient during scan) in the CT images.

The algorithm is applied to image segmentation using fuzzy C-Means and Watershed. Finally the kidney and tumor regions are separately segmented from the CT image. From the experimental results, it is concluded that fuzzy C-Means gives the better classification accuracy than Watershed.

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