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IMAGE SEGMENTATION TECHNIQUES FOR SCINTIGRAPHY IMAGE SEGMENTATION

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ABSTRACT

Scintigraphy image segmentation is an inspiring task in the field of image segmentation, as the capturization of scintigraphy images is made through the gamma camera having the ability to detect infected body cells. The injection of radioactive substance in human body is made through a vein in foot or hand. Emission of radiations of this substance are useful for the identification of infected body cells. This paper majorly concerns over the region-based segmentation, edge-based segmentation and thresholding methods for image segmentation. Chan-Vese model in region-based image segmentation is of major interest, which is an active contour model useful for object detection where the detection of boundary through gradient is not necessary. Chan-Vese model is highly recommendable for solving the problem of energy minimization by following the level set functions. Various research papers over scintigraphy image segmentation, Chan-Vese model, and thresholding methods for image segmentation are discussed in this review paper.

KEYWORDS: Image segmentation, chan-vese model, scintigraphy images, thresholding, active contours

1. INTRODUCTION

Image segmentation is the most popular fundamental of the image processing that focuses on the image apportioning in the evocating parts by maintaining the original image features. In concern of segmentation, main area of focus is simplification that relies image representation in a scrutinize manner. As we can say, image analysis is the foremost step of the image segmentation.

The goal of image segmentation is to partition an image into some non-overlapping areas where every part has its own homogeneous intensity. Image segmentation is primarily useful in medical imaging, video surveillance, content-based image retrieval, automatic systems for controlling the traffic, detection and recognition of objects, and many more [1].

Basically, image segmentation is of two kinds: one is local segmentation and another is global segmentation. Local segmentation deals with some specific regions or parts in the image, whereas global segmentation deals with the whole image, which is the collection of large number of pixels.

Various problems are occurring while performing image segmentation on an image. The problems like image having complex background, image with some form of noise, images having wispy and clutter targets, too large size of image, blurry images, presence of low light while capturing image, and also sometimes environmental conditions may affect the image capturing, and cause some irregularities in the image. Our main focus is on scintigraphy images. Scintigraphy images are those images which are captured by gamma camera. Thus, scintigraphy is also termed as Gamma Scan [2]. In nuclear medicine, scintigraphy is a test for diagnosing the abnormalities in the scanned image, in which a radioactive material is injected in the body through a vein in arm, hand, or foot. Then, radiations emitted by the injected radioactive material are used by gamma camera for performing the body scan, and identifying the affected body tissues.

For segmenting an image, there are seven methods namely threshold method, edge-based method, region-based method, cluster-based method, watershed method, partial differential equation-based method, and artificial neural network-based method. These are shown in figure give below:

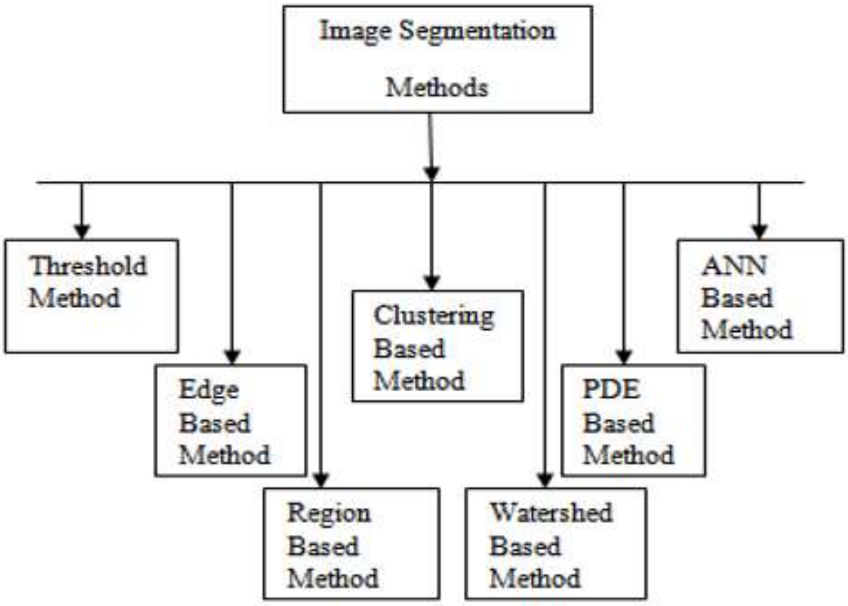

Figure 1: Various approaches for image segmentation [1]

All the segmentation methods are used for different kinds of images and for segmenting different regions of an image. According to our study, we will discuss some of them in detail. These are as follows:

1. **Threshold Method:** For segmenting an image, this method is quite efficient, simple and widely used method. Threshold method works by dividing the pixels of an image regarding their distinct levels of intensity. This method is preferred only if image having dark background and light objects. For dealing with complex images, multilevel thresholding is used, which is an extension of bi-level thresholding [3]. Thresholds can be manual as well as automatic, on the basis of user requirement and knowledge, with the ease of work. In basic manner, three kinds of thresholding values are there, global, variable, and multiple.

In global thresholding, a suitable threshold value T is used for an image p(x,y). Over the whole image, threshold value T remains constant, and by using this value T, we can get output image q(x,y) as follows:

$$q(x,y) = \begin{cases} 1, & if\ p(x,y) > T \\ 0, & if\ p(x,y) \leq T \end{cases}$$

In variable thresholding, on the basis of type of image, variations can occur in the threshold value T. This variation can be local or adaptive, where for local thresholding, threshold value T depends on the neighbors of x and y, and in adaptive thresholding, threshold value is considered as a function of x and y.

In multiple thresholding, multiple values of thresholding can occur as T0 and T1. With the help of these values, we can compute the output image as follows:

$$q(x,y) = \begin{cases} m, & if\ p(x,y) > T1 \\ n, & if\ p(x,y) \leq T1 \\ 0, & if\ p(x,y) \leq T0 \end{cases}$$

2. **Edge-based Method:** This kind of segmentation is based on rapidly changing the values of intensity in an image which is to be processed, because with a single-valued intensity, we can get enough information regarding the edges of the image. Edge detection techniques are working with two conditions where first is,

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1st order derivative of intensity > threshold (T), and second is, 2nd order derivate contains zero crossing values. With the use of edge segmentation methods, initially, detection of edges is made, after that they are connected altogether in order to create the boundaries of object, so that user can get the desired segmented region. Edge based methods are of two kinds, first is gradient-based method and second is gray histograms. Also, some operators like Canny, Sobel, Robert, and Prewitt can be used for detecting the edge in an image. These operators are 2D or 3D masks which are applied on the image, to get a new image [4].

3. **Region-based Method:** These methods are responsible for segmenting distinct regions having some similar properties. This method works with two techniques: one is region growing techniques, and another is region splitting and then merging.

1.1 Need of Scintigraphy Image Segmentation

Scintigraphy images are widely used in medical industry especially for cancer detection and treatment. Those are also useful for detecting the affected tissues in human body by monitoring and evaluating the organs. For retrieving the scintigraphy images, radioactive substance is injected to human body for exploring the radioactive radiation. For capturing the intensity of emitted radioactive substance, a particular camera is used namely Gamma Camera. The collimator named component in this camera plays an important role for providing a high quality scintigraphic image.

As the wide usage of scintigraphic images in medical diagnosis, there is a great need for the segmentation of scintigraphic images. For this purpose, a wide variety of algorithms have been proposed and are discussed in the section 2 of this paper.

2. LITERATURE REVIEW

Different researchers have made great efforts for segmenting the images and proposed a number of algorithms that helped to improvise the performance of segmentation results of image. (Ben Fadhel, Ktata and Kraiem, 2016) specified that there was a great need of image segmentation in medical imaging. Authors made work on identification of left ventricle in scintigraphy images by making the use of chan-vese algorithm with a specified threshold value [4]. In concern of enhancing the diagnosis quality, localization of organs in scintigraphy was identified in an improved manner. Authors made the preprocessing of image and then apply two segmentation approaches where one was region-based segmentation and another was threshold method. The preprocessing stage was the series of steps that were to be followed to process the original image. These steps are shown in the following figure:

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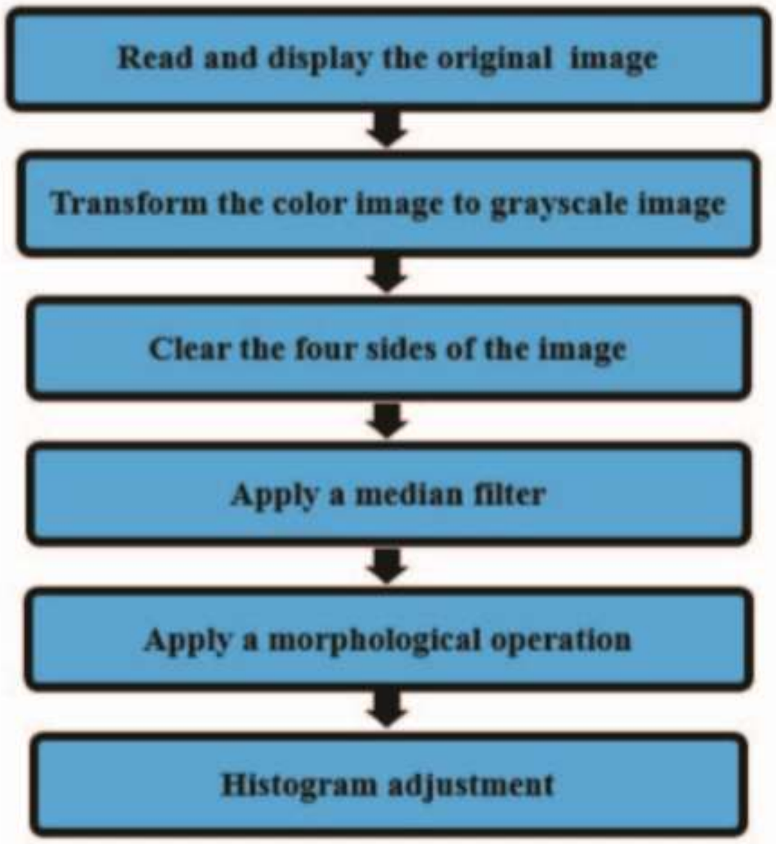

Figure 2: The Preprocessing Algorithm [4]

In concern of region-based segmentation, their first task was the detection of homogeneities and second task was the detection of common features by making the use of combined techniques including chan-vese method and thresholding methods. In order to deal with the edge boundaries, authors made the use of derivative methods in which, most preferable were the canny operator, sobel operator, and prewitt operator. From their work, authors specified that the results were good only with the combination of chan-vese and threshold techniques, whereas edge-based segmentation was unable to provide the expected results. Also, there was a problem to identify the manual threshold value.

On the basis of our work, literature review is done in three different aspects, one regarding chan-vese model, second regarding scintigraphy images, and third regarding thresholding methods.

2.1 Chan-Vese Model

(Song and Peng, 2019) presented an approach for intensity inhomogeneous images named fast two-stage image segmentation with the help of an energy-based function over a local region-based active contour model by making the use of exponential families [5]. At preliminary stage, authors segment the down-sampled images with the help of local correntropy-based K-means clustering model that worked for obtaining the coarse segmentation results in a fast manner along with the low computational complexity. After that, with the use of up-sampled contour of preliminary stage, authors segmented the original images with same method in more precise manner. At this stage, Song and Peng achieved accurate results with proper initialization in a rapid manner. Along with this, authors converged the two-stage energy function with the use of Riemannian Steepest Descent Method. By comparing proposed method with another numerical statistical methods for solving PDE's like chan-vese model, geodesic active contour, local binary fitted method, and local correntropy-based K-means clustering model, it was found that proposed method was able to get global minima in least iterations. Also, authors found that the proposed

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method has some dependence on the initialization up to some level, and this method is unable to segment the images with wispy and clutter targets.

(Yuan, Monkam, Li, Song and Zhang, 2017) proposed a new region-based active contour model for level set formulation where formulation of energy function can be made by making the use of global as well as local fitting terms of intensity [6]. The evolution equation of this proposed method was composed of three terms namely local, global, and regularization. Laplace operator was introduced by the authors in regularization term for regularizing the level set function at the time of evolution process, that helped in eliminating the cost of reinitialization in an efficient manner. Authors made a discussion on chan-vese model, local binary fitting model, and local and global binary fitting method. In order to test the proposed model, authors used a variety of real as well as synthetic images, and made a comparison with other three methods discussed above. From the comparative study of variant images, it was found that proposed method provides best results due to its ability to handle the intensity inhomogeneity with the integration of global and local intensities. As proposed method is a combination of gaussian distribution with active contours, so it increased the complexity of the method which took more time to segment the images. Some sort of fast algorithms can be further used to enhance the effectiveness of the proposed system.

(Soomro, Munir and Choi, 2018) presented a two-stage method for image segmentation that uses edge-scaled energy functional on the basis of intensity information of local and global intensities [7]. At initial stage, the integration of geodesic edge term with global intensity information was made to produce the results of rough segmentation. By considering the final contour of first stage as initial contour for the next stage, the integration of geodesic edge term with local intensity information was used for producing the result of final segmentation. In order to regularize the level set function, gaussian kernel was adapted for avoiding the re-initialization procedure which was very expensive. A quick review was made on mumford and shah model, geodesic active contour model, edge-scaled region-based active contour model, local binary fitted model, and chan-vese model. Experiments were performed on various different images, and proposed method results were compared with the results of other methods specified above. This comparison showed that chan-vese provided results in least number of iterations and least CPU time, but the results were not desirable, whereas proposed method provide desirable results in more time and with higher number of iterations.

2.2Scintigraphy Imaging

(Aslantas, Emre and Çakiroglu, 2017) discussed that bone scintigraphy is most widely used procedure for diagnosing the nuclear medicine in order to detect the bone metastases. The detection of involvements made by the process of imaging are termed as hotspots [2]. The main concern of authors was on successfully segmenting the hotspots that may affect the CAD system accuracy and be able to detect the bone metastases. Authors have examined the extent up to which the success rate of CAD systems may get affected by segmentation algorithms. It was already specified that no segmentation algorithm is perfect for all types of images. With the use of this proposed system, authors compared various algorithms of segmentation that can detect the hotspots. From experimental study, it was observed that self-organizing map network (SOM), level set active contour (LSAC) and fuzzy c-means (FCM) were providing best results in concern of all angles and details. From their performance measures, it was confirmed that LSAC provided most appropriate results for segmentation algorithm, and accuracy for each segmentation method was measured and then compared, where FCM had 84.62%, SOM had 86.93%, and LSAC had 92.3% accuracy. A major concern was made on measuring tolerance of segmentation algorithms by calculating the error rates for these three. The results for sensitivity and specificity were also compared. By deeply reviewing the paper, it is found that SOM algorithm failed to provide same results in every situation due to some errors in mapping. Also, there were some incorrect regions identified by SOM and FCM due to poor resolution of some images used for experimentation.

(Tsujimoto, Teramoto, Ota, Toyama and Fujita, 2018) developed a method to automatically detect the integrated sites of higher manner in SPECT images with the use of information about bones which were taken through CT images of bone scintigraphy [8]. In this method, authors initially extracted the bones from CT images with the segmentation of multiple regions. This region was correspondingly extracted in the SPECT images as well. After that the values of increased uptakes were calculated for all bone regions and were specified through quantitative index. In order to verify the method efficiency, an assessment was performed by making the use of clinical data as well as phantoms. The creation of phantoms was made by changing the concentrations of radioactive substance.

From this assessment, 71% sensitivity was specified in increased uptake regions and the value of correlation between automatic measurements and manual measurements was 0.868, which is highly significant. From this, it was obvious that automatic detection can be made for increased uptake regions in SPECT image with the help of information regarding bones obtained through CT images.

2.3 Threshold Method

(Lei and Fan, 2019) discussed image thresholding based with the usage of rough entropy as the most efficient technique for image segmentation [9]. There were some existing optimal threshold methods that leads towards some uncertain path. However, this new path leads to a new shape in the category of determination of image roughness with the help of square rough entropy. Lei and Fan proposed and presented an algorithm for image segmentation by making the involvement of thresholding methods. A variety of good properties along with the computations are provided by novel square rough entropy algorithm. A computation was made for optimal threshold by separating the object boundary from the image background. A consistent process was followed to refine the image in an effective manner with the help of histogram homogeneity using size selection method. By comparing the proposed algorithm with some other algorithms of same category, it was found that proposed algorithm provides good segmentation results by maintaining the simplicity in code.

(Elaziz, Bhattacharyya and Lu, 2019) discussed the concept of multilevel thresholding for segmenting the images. A variety of algorithms have been found for dealing with the threshold values but there are some limitations in metaheuristic methods namely premature convergence and high computation complexity. In order to deal with such issues, swarm selection algorithm is engaged with multilevel thresholding with the use of differential evolution algorithm [10]. Main criteria behind the usage of differential evolution algorithm is to deal with the combination of some algorithms to maximize the value of Otsu's function by determining the optimal threshold values. Six images were used for testing by performing an experimental series by involving nine levels of threshold. Proposed algorithm's performance was compared to non-hybrid as well as some hybrid algorithms. Some performance measures preferably structure similarity index, computation time, peak signal to noise ratio and value of fitness function were determined and compared, and it was found that suitable results were obtained in low computation time.

3. CONCLUSION

Image segmentation is a way to segment some region of an image for extracting useful information from that segmented region. There are various methods of image segmentation, and these methods are useful according to the variant situations like images with intensity inhomogeneity, noise conditions, images with clutter edges, and many more. Also, variation among images has been noted due to their distinct types like flower images, medical images, scintigraphy images, synthetic images, or real images. This paper especially focuses on segmentation of scintigraphy images which are nuclear images captured through gamma camera for extracting the information about affected body regions by harmful tissues. Three segmentation techniques namely thresholding methods, region-based methods and edge-based methods are discussed. In region-based methods, chan-vese algorithm is of main concern. Chan-vese model is a popular active contour model without edges for image segmentation. This model works by detecting the objects rather than edges. Chan-vese model is a combination of reduced mumford-shah model and level set methods. The wider usage of this method is for solving the energy minimization problems, by segmenting the image regions into two parts, where one is the background and another is the target. As chan-vese is most useful model for image segmentation, but still there are some drawbacks in this algorithm. Chan-vese model is not providing desirable results with images having intensity inhomogeneity. In case of complex background, segmentation results are inappropriate. Chan-vese model works well if the location of initial contour is right, but if it is wrong, then it consumes more time. Identifying the right location of initial contour is a difficult process. Thus, there is a great need to improve the chan-vese model so that image segmentation can be achieved in minimum time with desirable results.

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