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A comparative study of new and existing segmentation techniques

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Abstract— Image segmentation is the most crucial part in image processing techniques. Numerous segmentation techniques are used to segment digital images into smaller regions called segments, consisting of sets of pixels in order to analyze important information from the images. Segmentation simplifies the process of information retrieval from the region of interest (ROI). It helps in converting the digital image into more relevant information and easier to analyze. This paper presents a comparative analysis of existing segmentation techniques and its modification to form new segmentation techniques to overcome some of the drawbacks of the existing image segmentation approaches.

Keywords—pixel, cluster, thresholding, watershed transform, edge detection

1. INTRODUCTION

Image segmentation is an important step in computer vision. It is applicable in various fields in real life. Some of the important fields where image segmentation comes into play are medical imaging, video surveillance, object detection and recognition, retrieval of images with contents and automatic traffic control systems, to name a few. Recently medical field has been using segmentation techniques to extract meaningful information from its medical images which in return help in treatment planning and diagnosis.

Segmentation divides an image into multiple segments by clustering similar pixels together on the basis of color, intensity, texture or volume. Over more than a decade, many segmentation techniques have been proposed by the authors to enhance the level of accuracy and effectiveness of the segmentation results. However, a single segmentation technique cannot be considered to be effective if a comparative analysis is made for all the existing techniques. Therefore, digital image segmentation still remains a challenging task for many researchers. The decision making process of which technique would best segment a digital image in a particular field is yet not defined. The application which is considered in this paper to compute the comparative analysis of various segmentation techniques is the medical imaging field. Medical images have widely used image segmentation techniques to segregate input images and retrieve important knowledge about the region of interest. The ROI can be cancerous cells, tumor tissues or lesions. The results of segmentation is very crucial and important and demands high accuracy level as it is on the basis of these results that the doctor prescribes diagnosis to their patients. Therefore, a lot of research is going on in this field to improve the effectiveness of the



segmentation methods. The rest of the paper consists of existing segmentation techniques in section 2. Section 3 describes a comparative analysis of the new segmentation methods proposed in the recent times, while section 4 describes some of the results of the existing research work. Section 5 concludes the analysis of the new and existing segmentation techniques.

2. EXISTING SEGMENTATION TECHNIQUES

There are many image segmentation techniques proposed to segment the images to retrieve essential knowledge and information out of it (figure 1). All of the techniques vary in their method used for segmenting the images [16]. Some of the popular techniques used for image segmentation are as follows:

2.1 Thresholding

Thresholding is one of the most popular segmentation techniques which convert the greyscale image to a binary segmented image [15]. The procedure of thresholding works as follows. It compares the intensity level of the pixels present in the image. It replaces the original pixel with a black pixel when the intensity of the point is less than the predetermined threshold value otherwise it replaces the pixel with a white pixel.

2.2 Edge detection segmentation

This technique highlights the idea of rapid change of pixel intensity value in an input image [16]. The reason behind this is that only one pixel value intensity would not give accurate information about boundaries. Here, the algorithm starts by detecting the edges of the images. Then these edges are linked with one another to form the boundary of the tissues of interest to segment the region further. The edge detection technique is a structural technique based on discontinuity detection and the resultant image is a binary image.

2.3 Region based segmentation techniques

This technique segments the CT image into several regions with same characteristics [16]. In region growing segmentation method, these segmented regions are partitioned on the basis of the initial pixels. These seeds are selected on the basis of prior knowledge manually or automatically on the basis of some application. In region splitting and merging based segmentation, as a primitive step the image is divided into many spaces having same characteristics and then adjacent regions with some similarity are merged.

2.4 Clustering techniques

Clustering techniques are classified as hard type and soft type clustering.

2.4.1 Hard type clustering method. It results in a definitive segmentation. The concept behind hard type clustering is that one particular pixel can belong to at most one cluster. Hence if an image has poor contrast and low resolution, this technique would not produce efficient outcome. K-Means Clustering Algorithm is an example of hard clustering where each pixel is being categorized to belong to one cluster only. K-Means Clustering segments the image into several partitions and every pixel belongs to the cluster with the nearest mean.

2.4.2 Soft clustering technique. It assumes that each pixel in an image can belong to more than one cluster. It assumes that there is an equal probability of a pixel to belong to all the clusters. Also it says that a pixel might partially belong to a cluster or more. This method is very popular in medical field to identify important regions in an image. Fuzzy C-Means Algorithm (FCM) works in this technique. In FCM, each point in the CT image might belong to one or many clusters depending on the membership degree, unlike hard clustering where each point belongs to a single cluster only. This helps in effective performance for images with low and poor contrast and resolution, thus solving the problem encountered in hard type clustering algorithms. This also gives better results in CT images with region overlapping problem.

However, researchers have found that Fuzzy C Means segmentation technique is very much susceptible to noise [17].

2.5 Watershed segmentation

Another segmentation method used extensively is known as Watershed segmentation [2]. Here, pixel and region similarity is found. For each pixel identified, the region to which the pixel should belong is computed. The algorithm starts with the watershed transform function being defined. However, this scheme results in an over segmented image most of the time.

2.6 Partial differential equations

Another segmentation technique which works on the idea of computing the differences between the pixels of an image continuously is the Level Set Segmentation method. This segmentation is based on the principle of partial differential equations (PDE). PDE techniques are computationally faster and hence would benefit applications with critical time period. Basically PDE works in two different ways, one for edge enhancement in the images and another way to discard or remove noisy elements from the image [16].

2.7 Artificial neural network

The AI based segmentation techniques uses the concept that human brain can learn in order to make decisions [16]. This segmentation technique is extensively used in medical image segmentation process as it separates the useful information of the image from the background. This problem is transformed to issues that can be solved using neural network by extracting the important features and then segmentation of the medical image.

Some segmentation techniques use evolutionary methods which are based on Genetic Algorithms.

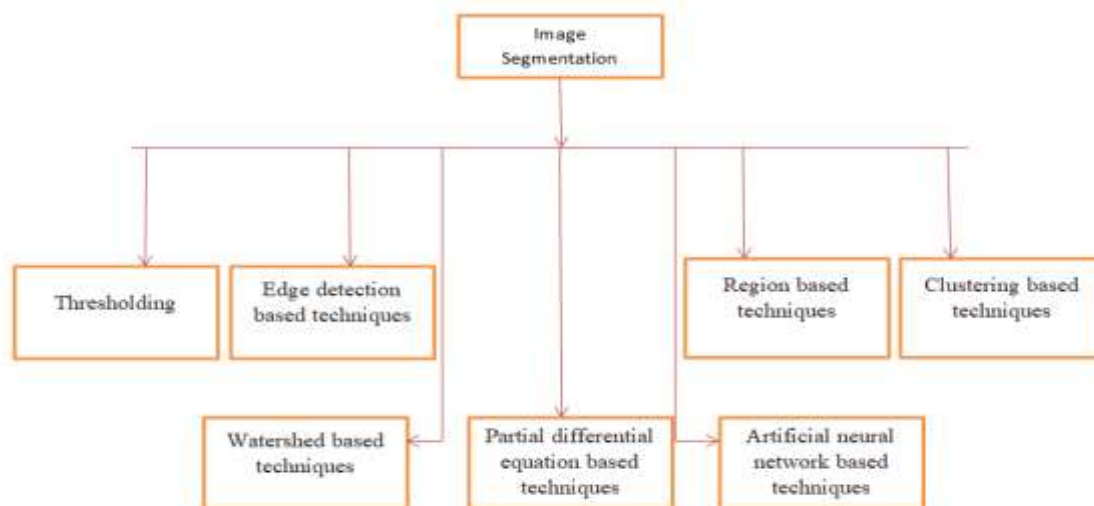


Figure 1: Types of Segmentation

3. MODIFICATION OF EXISTING SEGMENTATION TECHNIQUES TO NEW SEGMENTATION TECHNIQUES

Analyzing some of the shortcomings of the existing segmentation techniques found in various applications of digital image segmentation fields, researchers tried to overcome these pitfalls by modifying the existing segmentation techniques to find new and improved segmentation techniques. Moreover, the knowledge of the exact location of region of interest and its volume is a challenging task. Also ROI's present low contrasted boundaries sometimes and exhibit a large variability of shapes, sizes

and locations in the digital images. This section of the paper discusses about the new segmentation techniques and how they have been immensely used in various applications of digital image processing.

3.1 Marker Controlled Watershed Segmentation

A modification of the watershed technique is called Marker Controlled Watershed Segmentation. In order to overcome the problem of over segmentation in watershed transform, Marker-Controlled Watershed Segmentation is proposed where certain elements are predetermined in a digital image. One of the most important tasks to be accomplished during segmentation of medical images is separating the neighboring tissues of organs from the tissues of interest as in most of the cases the neighboring organ tissues might have similar intensities and fuzzy boundaries as that of ROI. The watershed transform technique is often used in such cases to separate the touching organs from the organ of interest. But this technique has few drawbacks like oversegmentation, sensitivity to noise and also unable to detect areas of low contrast boundaries. However, marker controlled watershed transform overcomes this problem by predetermining the number and possible localization of the region of interest using a marker function.[1] Hence it is efficient to use marker controlled watershed transform over watershed transform technique as it overcomes the drawbacks of watershed transform.

Stawiaski et. al.[2] proposed a model to segment liver tumors using watershed and graph cut algorithm. It was concluded by the author that the time required to segment tumor using watershed algorithm is negligible as compared to a standard graph cut algorithm, thus improving the efficiency of watershed transform segmentation technique in terms of time required to implement a segmentation process. Thus, it is effective to use marker controlled watershed transform over watershed and graph cut algorithm with respect to accuracy of results and time.

In another research paper, authors make use of watershed transform algorithm with texture based region merging for segmentation of organs [3]. The results computed achieved 92.2% accuracy as compared to other segmentation approaches. Hence this research also proves that use of marker controlled watershed algorithm provides much better accuracy than any other segmentation techniques.

Prasad, D. V. R found that Marker Controlled Watershed Segmentation approach has more accuracy (85.165%) than Thresholding approach (81.835%). Moreover it was also concluded that the quality of the segmented image is much better when marker controlled watershed transform is implemented [4].

Rahman and Goud [5] used marker controlled watershed transform and K-Means clustering techniques for CT image segmentation. Tumor cells are identified in the CT scans of lungs to detect cancer in the lungs of the patient. Results show that marker controlled watershed transform provides better results of segmentation as compared to K-Means clustering techniques in terms of accuracy of segmented images. Also, the calculation time required by watershed is less than the time required by K-Means. This paper presents a technique for early detection and diagnosis of lung tumors by enhancing the quality of the CT images and segmenting the CT images. Authors have also taken time factor into account to detect the abnormalities in the lung tissues. The proposed marker controlled watershed division strategy perfectly isolates the neighboring organ tissues from the region of interest and gives 100% exactness.

Kanitkar et. al. have proposed a model to detect tumors in lungs. It also tries to calculate the cancer stage by using segmentation and enhancement techniques. It was concluded that Marker controlled watershed transform performs the best with 100% accuracy in detecting the tumor tissues in the CT lung images than thresholding or any other existing techniques [6].

Another group of authors proposed an intuitive method to segment gray and white matter in MR images using watershed transform [7]. It was found by analysis that this method is fast in computation and also simple to be implemented. Moreover, watershed transform divides the regions into complete divisions even in cases of low contrast CT images. This reduces the effort of post processing such as contour joining.

Chen and Wenzhou [8] proposed a morphological reconstruction approach based on watershed transform with the help of internal and external markers. The results obtained were very satisfactory and the accuracy level was higher than many other existing segmentation techniques.

Amanpreet and Ashish [9] performed a survey on various segmentation techniques and after analyzing the results concluded that marker controlled watershed transform performs the best in terms of accuracy as it marks the regions before segmenting the image. However, optimization of the marking regions is a problem. This drawback can be overcome by utilizing a combination of marker controlled watershed transform and median filter to improve the performance of the segmentation algorithm.

3.2 Deep learning techniques

Deep learning techniques are recently used extensively for image segmentation. These techniques focus on training the classifier system to be used. The classifier is trained by automatically extracting and selecting the features of ROI. These mechanisms have proved to be more efficient as compared to many other machine learning approaches. But it requires a large amount of data as training data set [19]. Hence, use of this technique is limited to real world cases only as finding large data sets which are publicly available is a tedious job.

M. Freiman et. al. proposed a new and nearly automatic method for segmentation of liver tumors [10]. SVM (support vector machine) classifier is used to classify the healthy tissues and tumor tissues from the CT images, which lead to the generation of new set of high quality seeds. This proposed method is efficient, robust and is comparable and effective than many other semi-automatic techniques.

Authors in [11] proposed a fully automatic segmentation algorithm to detect tumors in livers from the CT images of patients. The novelty of this technique was to combine follow up based detection with convolutional neural networks (CNN). CNN is trained to construct a voxel classifier with automatic feature learning. This method is robust and more efficient in terms of accuracy and an improvement of 60.29% in comparison to other methods.

In another research paper, a fully convolutional neural network is proposed which results in more precise segmentation of ROI. The resulting model is basically applicable to biomedical segmentation problems [12]. The applicability of this model to biomedical segmentation resulted in very good performance with a very few training data sets. The model is efficient in terms of time duration required for training as well.

P. F. Christ [13] proposed a CNN to segment liver and lesions in CT images of abdomen of patients. The cascaded FCN approach provides enhancement in segmentation accuracy when its accuracy is compared to single fully convolutional networks.

3.3 Otsu Thresholding

A modification of thresholding segmentation method is called Otsu Thresholding. Otsu thresholding classifies the image into two different classes naming foreground and background. The different intensity value pixels in the image are iterated on either side until the inter-class variance is minimal.

This technique was used by the authors in research [14] for detection and extraction of brain tumors from MRI scan of the patient. In another research paper, efficient and accurate brain tumor detection and segmentation is carried out using thresholding and some morphological operations [15].

3.4 FCM with advanced optimization techniques

FCM is based on pixel intensity values only and is very susceptible to noise. In order to overcome this issue, spatial relations between pixels have been proposed to be added along with FCM to enhance its performance by many authors [16]. This modified version of FCM has proved to be more effective in segmentation results.

Fuzzy C Means (FCM) is used to detect the tumor regions in brain from complex MRI scans. In the first phase, preprocessing and image enhancement is performed while in the second phase segmentation of brain tumor and its classification based on a learned classifier is performed. Certain effective optimization tools are also used to detect the tumor. Some of the tools are Genetic Algorithm (GA), and Particle Swarm Optimization (PSO) [17].

J.selvakumar et. al. [18] proposed a model for detection of range and shape of brain tumors and its segmentation by combining the algorithms of advanced K means and Fuzzy C-means. This method of combining two algorithms has proven to be accurate enough and reproducibility is also high as compared to some manual segmentation approaches. The time duration for image segmentation is also found to be comparatively less in the case of combined advanced K means and Fuzzy C-means algorithms.

Moghbel et. al. [20] proposed a segmentation method which is fully automated with no user interaction for liver tumor segmentation. They proposed a hybrid method combining fuzzy c-means, cuckoo search based optimization and random walkers algorithm. Fuzzy C-means is used for clustering where each pixel is considered to be belonging to more than one cluster in order to improve the performance in images with poor contrast. To further increase the accuracy of the segmentation of liver, a metaheuristic approach called cuckoo optimization is implemented. For proper handling of noisy images and blurred edges of the CT scans, a method based on supervised learning called random walkers algorithm is implemented. This model provides accurate segmentation results and it can be easily included in any CAD system for tumor segmentation from medical perspective.

TABLE 1 : Comparison of segmentation techniques

Methodology	Description		
	Merits	Demerits	New technique proposed
Thresholding	1.Easy to implement 2.low computational cost 3. smaller storage space 4.Fast processing speed	1. Sensitive to noise and grayscale unevenness. 2. Results are not accurate when there is overlap of grayscale values.	Otsu Thresholding
Edge detection segmentation	1.Preserves the boundaries of images with high contrast.	1.Manual intervention is required. 2.Cannot sense noise	NA
Region based segmentation techniques	1.Easy to implement 2.Noise resistant	1.Manual intervention is required. 2.High computational cost in terms of time and memory.	Hemitropic region-growing algorithm[25]
Clustering techniques	1.Easy to implement 2.low computational cost	1.Very susceptible to noise. 2.Membership function calculation is difficult.	FCM with advanced optimization techniques
Watershed segmentation	1.Simple and intuitive 2.Algorithm can be parallelized. 3.Results in complete division of image.	1.Over segmentation 2.Manual intervention is required. 3. Sensitivity to noise. 4. Poor detection of significant areas with low contrast	Marker Controlled Watershed Segmentation

Methodology	Description		
	Merits	Demerits	New technique proposed
Partial differential equations	1.Fastest computation	Boundaries 1.Accurate initialization and implementable functions required	NA
Artificial neural network	1.Fast segmentation technique and hence less run time complexity. 2. High results w.r.t sensitivity and accuracy.	1.Time wastage during training phase 2.Works well with large ROI.	Deep learning techniques

4. RESULTS AND DISCUSSIONS FROM EXISTING RESEARCH WORK

Many authors have tried to perform segmentation on the same set of medical images using various segmentation techniques. In one of the papers, Gajanayake et. al.[21] compared various standard segmentation techniques for detection of brain tumor and concluded that Otsu's thresholding method is very suitable for segmenting 2D MR images to identify tumor tissues. Gupta et. al. made an analysis on the comparative study of different medical image segmentation techniques for tumor detection in brain [22]. Sensitivity and accuracy of local based projection method is better than other methods of segmentation. In another research paper, a combination of OTSU thresholding and watershed transform algorithm is proposed to resolve the problems of oversegmentation and cell adhesion [23]. The results of segmentation of this hybrid algorithm have been more accurate than the existing watershed transform. In another research work [24], a performance comparison between three segmentation techniques, iterative thresholding, region and fuzzy region based level set method is done by the authors to identify the best image segmentation technique for lung nodule detection in computed tomography. Fuzzy region based level set method outperforms the other two segmentation techniques. Some of the applications and its results are mentioned below.

TABLE 2: Results of some segmentation methodologies

Application	Methodology	Results
Liver Tumor Segmentation	Watershed and graph cut algorithm	Watershed algorithm is more efficient in terms of accuracy of results and time
	Convolutional Neural Networks	CNN is more efficient in terms of accuracy and an improvement of 60.29% is achieved.
	Fuzzy c-means, cuckoo search based optimization and random walkers algorithm	Accurate segmentation results(MOE==22.78 % and DSC= 0.75 in 3Dircadb dataset, MOE= 15.61 % and DSC= 0.81 in MIDAS dataset)
Lung cancer detection	Various image processing techniques	Marker Controlled Watershed Segmentation approach has more accuracy (85.165%) than Thresholding approach (81.835%)

Application	Methodology	Results
Brain tumor segmentation	Marker-Controlled Watershed Transform and K-Means Clustering Thresholding, morphological operations and extraction of features of tumor K means and Fuzzy C-means algorithm	Marker Controlled Watershed Segmentation gives 100% exactness. Computationally fast as compared to hybrid segmentation and segmentation accuracy is also high. Computationally fast and reproducibility is high.
Medical image segmentation	Watershed segmentation with texture-based region merging	92.2% accuracy achieved with watershed algorithm.

5. CONCLUSION

The idea of this paper is to present a comparative analysis of well-known existing image segmentation methods with new segmentation methods to identify the most suitable method for the segmentation of medical images. It has been analyzed that the accuracy of results found in hybrid combination of existing algorithms is much higher as compared to single algorithm approach. Also that the modified versions of the existing segmentation techniques can many a times outperform the old approaches of segmentation. Basically in most cases it has been observed that the modified techniques try to overcome the drawbacks of the old segmentation techniques. Every segmentation algorithm has its own advantages as well as disadvantages. There is still a lot of future scope in proposing segmentation techniques with high accuracy, sensitivity and less time complexity.

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