Image Segmentation Techniques: A Review

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Abstract- Image segmentation act as a judging or analyzing function in image processing and analysis. Image segmentation is generally used to cut out region of interest (ROI) from an image. Its results have an effect on image analysis and it requires higher order tasks. Image analysis includes object description, representation and feature measurement. Currently there are many different algorithms available for image segmentation. Each has their own advantages and purpose. In this paper, different image segmentation techniques with their prospects are reviewed.

Keywords- *Image segmentation; edge; thresholding; K-means; fuzzy; neural.*

I. INTRODUCTION

In the field of computer vision, images are considered as the most important medium for conveying information. The information extracted from them can be used for other tasks for example: finding injurious tissues from body, detection of cancerous cells. Now a strong method is needed which can be used for understanding images and extract information or objects. Thus, image segmentation fulfill the above requirements. Image technique can be grouped under a general framework of image engineering (IE). Image Engineering is made up of three layers. The upper layer as image understanding, middle layer as image analysis, lower layer as image processing, as shown in figure 1. Image segmentation is the foremost step and one of the most difficult tasks of image analysis, which has an objective of extracting information so as to represent in the form of data from image via image segmentation, feature measurement and object representation as shown in figure. Segmentation is the process of partitioning a digital image in to multiple regions and extracting a meaningful region known as the region of interest (ROI) from it. The result of segmentation of image considerably depends on the accuracy of feature measurement [1].

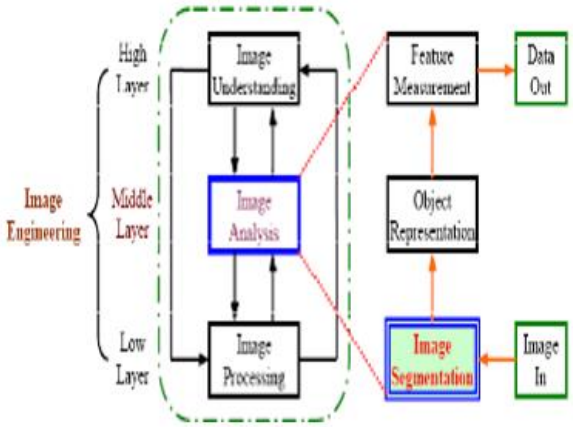

Fig. 1 Image engineering and image segmentation [1]

II. SEGMENTATION TECHNIQUES

In recent years, a lot of research has been done in the field of image segmentation process. There are currently a number of algorithms, each doing the segmentation process slightly different from another, but still we do not have any particular algorithm that is applicable to all types of digital image, fulfilling every objective [1, 10]. Image segmentation algorithms are based on either discontinuity principle or similarity principle. The main idea behind the discontinuity principle is to extract regions that differ in properties such as intensity, color, texture, or any other image statistics. The idea behind the similarity principle is to group pixels based on common criteria (property) [2].

A. Segmentation based on edge detection

Edge carries a lot of information about the various regions in an image. They provide an outline of the object. An edge is said to be a set of connected pixels that lies on the boundary between two regions that differ in grey value. These pixels on the edge are called edge points [13]. Some of the edges that are usually encountered in image processing are as follows: Step edge, Ramp edge, Spike edge, Roof edge. Step edge is an

abrupt intensity change. Ramp edge represents a gradual change in intensity. Spike edge represents a quick change and then immediately returns to original intensity level. Roof edge is not instantaneous over a short distance. Edge detection technique is one of the structural techniques of the image segmentation process [12]. An edge detection operation is essentially an operation to detect significant local changes in the intensity level of an image. The change in intensity level is measured by gradient of the image [11]. Edge detectors have different operators based on gradient (derivative) function for detection of edge such as sobel operator, laplacian operator, canny operator, Log (Laplacian of Gaussian) operator and so on. Edge detection method requires a higher image quality so its need is to reduce or remove the noise.

B. Segmentation based on thresholding

One of the simplest approaches of segmentation is based on the pixel values. Thresholding is an old, simple and popular technique for image segmentation [7]. Image segmentation by this technique is a simple but powerful approach for segmenting images having light objects on dark background and vice versa [4]. Thresholding technique is based on image space regions i.e. on characteristics of image [1]. Thresholding operation converts a multilevel image into a binary image. It chooses a proper threshold T, which divide image pixels into several regions and separate objects from background. Thresholding procedure used to determine an intensity value called as threshold, and threshold separates the desires classes. The segmentation is preceded by grouping all pixels with intensity greater than the threshold into one class, and all other pixels into another class. Based on the selection of thresholding value, two types of thresholding methods are in existence [12], global and local thresholding. Nikhil R Pal and Sankar k Pal [10] done review work on image thresholding technique. Thresholding can be classified into bi-level thresholding and multilevel thresholding [6].

In bi-level thresholding all gray values greater than threshold T are assigned the object label and all other gray values are assigned the background label, thus separating the object pixels from the background pixel.

$$G(x, y) = \begin{cases} 1, & \text{if } f(x, y) > T \\ 0, & \text{if } f(x, y) < T \end{cases} \quad (1)$$

In multilevel thresholding the images are partitioned into different segments using multiple threshold values. The histogram in such case is multimodal with multiple values in between.

$$G(x, y) = \begin{cases} a, & \text{if } f(x, y) > T2 \\ b, & \text{if } T1 < f(x, y) \leq T2 \\ c, & \text{if } f(x, y) \leq T1 \end{cases} \quad (2)$$

Peaks and valleys of the image histogram can help in determining the appropriate value for the threshold(s).

When T is constant, the approach is called global thresholding else it is called local thresholding. Global thresholding methods are failed when the background illumination is uneven.

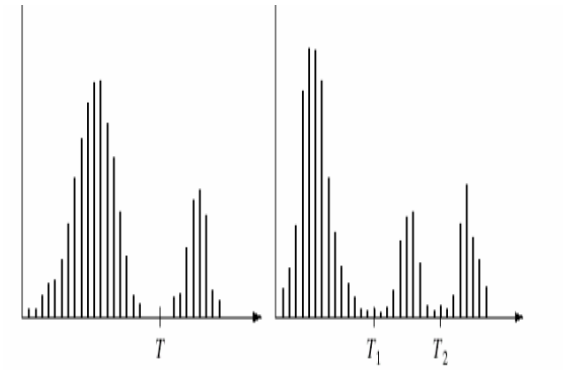

Fig.2: The histograms that can be partitioned (a) by single threshold (b) by dual threshold [6]

In local thresholding, multiple thresholds are used to compensate for uneven illumination [30]. The various factors which affect the suitability of the histogram for guiding the choice of the threshold are the separation between peaks, the noise content in the image, the relative size of objects and background, the uniformity of the illumination, the uniformity of the reflectance [6].

C. Region based segmentation

A region say R of an image is defined as a connected homogenous subset of the image with respect to some criterion such as gray level or texture. The regions in an image are group of connected pixels with similar properties. In the region based approach, each and every pixel is assigned to a particular object or region. Compared to edge detection method, segmentation algorithms which are based on region are relatively simple and more immune to noise [4, 8]. Edge based method partition an image on the basis rapid change in intensity near edges whereas region based methods, partition an image regions that are similar according to some

predefined criteria [9, 11]. In the region-based segmentation, pixels corresponding to a particular object are grouped together and marked. Region-based segmentation also requires the use of appropriate thresholding techniques. The important principles upon which it depends are value similarity (which includes gray value differences) and spatial proximity (which consists of Euclidean distance and compactness of a region).

Segmentation algorithms based on region mainly include following methods:

1) Region Growing

In this technique by some means we try to identify the seed points and then we try to grow the region from these seed points based on similarity criteria. So when we grow points on similarity criteria we make sure that a point will be included into particular region if intensity is similar to that region and a point is also connected to that region. Region growing refers to the procedure that groups pixels or sub regions into larger regions. Starting with a set of seed points, the regions are grown from these points by including to each seed point those neighboring pixels that have similar attributes like intensity, gray level texture, color, etc. It is an iterative process where each seed pixel grows iteratively until each and every pixel is fully processed and thereby forms different regions whose boundaries are defined by closed polygons. It presents several advantages over other color image segmentation algorithms. Region growing approach is simple. The border of regions found by region growing are perfectly thin and connected. The algorithm is also very stable with respect to noise. Limitation is that, it requires a seed point, which generally means manual interaction. Thus, for segmenting each region, a seed point is needed.

2) Region Splitting and Merging

Split and merge technique is the opposite of the region growing. This technique works on the whole image. Region splitting is a top-down approach. It begins with a whole image and divides it up such that the separated part is more homogenous than the whole. Hence, a merging phase after the splitting is always desirable. Therefore it is termed as the split-and merge algorithm. Any region can be split into sub regions, and the suitable regions can be merged into a region. Rather than choosing seed points, one can divide an image into a number of arbitrary unconnected regions and then merge the regions in order to satisfy the conditions of reasonable image segmentation. Region splitting and merging is usually implemented with theory based on quad tree data.

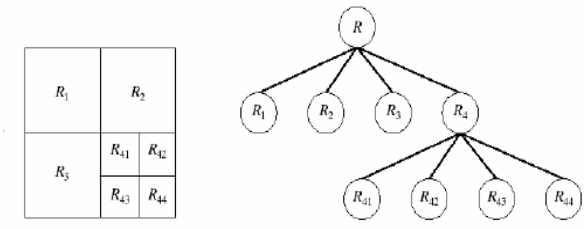

Fig. 3 Quad tree [6]

Region splitting and merging is an image segmentation technique that takes spatial information into consideration. The region-splitting and merging method is as follows:

3) Region splitting Method

In this case we try to satisfy homogeneity property. In it the pixels that are similar are grouped together. If the gray levels present in the region do not satisfy this property, we divide the region into four quadrants. If the property is satisfied we leave the region. This is done recursively until all the regions satisfy the property. To explain this in terms of graph theory, we call each region as a node. This node (parent node) is split into four leaf nodes. If the node satisfies the property, it is left as it is. If not, they are further split. This method is appropriate for those images whose no. of rows and columns are some integral power of two.

4) Region Merging Method

This method is exactly opposite to region splitting. Like splitting, it is also appropriate only to images whose no. of rows and columns are an integral power of two. In this method some seed points are needed to initialize the process, the segmentation results are dependent on the choice of seeds. Regions are grown iteratively by merging the neighboring pixels depending upon the merging criterion. This process is continued until all pixels are assigned to their respective regions as per merging criterion [3].

D. Segmentation based on clustering

Clustering [14] is an unsupervised learning task. Here one needs to identify a finite set of categories of available data. Clustering is mainly used when classes are known in advance. A similarity criteria is used for clusters to classify pixels [12]. Clustering use no training stages rather train themselves using

defined pixels [3], and then similar pixels are grouped together to form clusters. The pixels are grouped into clusters based on the principle of maximizing the intra class and the inter class similarity. The quality of a clustering result depends upon both the similarity criteria used by the method and its implementation. A good clustering method [24] will produce high quality clusters with high intra-class similarity. A standard procedure for clustering is to assign each pixel to the nearest cluster mean. Clustering algorithms are classified as hard clustering, k- means clustering, fuzzy clustering, etc. Hard clustering assures that a pixel can only belong to a single cluster and also that there exist sharp boundaries between the clusters. A popular and well hard clustering algorithm is the k-means.

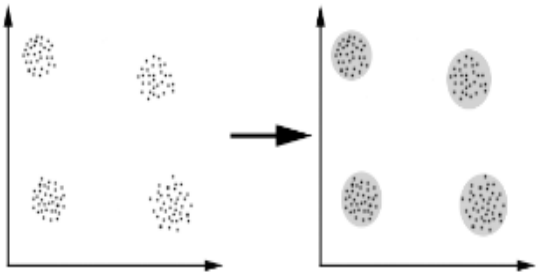

Fig. 4 Clustering [12]

1) K-mean clustering

K-means algorithm is one of the simplest clustering methods. K-means clustering is a technique which groups n pixels of an image into K number of clusters, where K < n and K is a positive integer. The purpose of k-means algorithm [23] is to cluster the data. It is the one of the unsupervised learning algorithm for clusters. Clustering the image is grouping the pixels according to the same characteristics. In the k-means algorithm initially we have to define the k number of clusters. Then k-cluster center are chosen randomly. The distance between the each pixel to each cluster centers are calculated. The distance may be of simple Euclidean function. The pixel which is having minimum distance is assigned to a cluster otherwise it is moved to the next cluster. The center is again re-estimated. Again each pixel is compared to all centroids. The process continuous until the center converges.

2) Fuzzy clustering

Fuzzy clustering is a powerful unsupervised method for the data analysis. In many situations, fuzzy clustering is more natural than hard clustering. The pixels on the boundaries between several classes are not forced to fully belong to one of the classes, but rather they are assigned membership degrees between 0 and 1 indicating their partial membership. Fuzzy c-means (FCM) is the clustering algorithm which works by assigning a membership value. It allows one piece of data may be member of more than one clusters. Fuzzy c-means algorithm is most widely used. Fuzzy c-means clustering was first reported in the literature for a special case (m=2) in 1974. It was improved by Bezdek in 1981 [17]. To overcome difficulties of the FCM, Krishnapuram and Keller [16] proposed a new clustering method known as Possibilistic c means (PCM). In this the distance was determined at which the membership value of a point in a cluster becomes 0.5. The advantage of PCM is it can cluster noisy data samples and disadvantage is that it is very sensitive to good initialization [16]. Membership values of the FCM can be renewed by considering the resistance of neighbors [19, 20] or feature-weight learning [21] to improve the performance of fuzzy c-means clustering. Numerous research groups and individuals have addressed the effectiveness with the modified object function of the FCM. Krishnapuram and Keller [18] have proposed the possibilistic approach that corresponds to the intuitive concept of degree of belonging and hence reduce trouble in noise environment.

E. Segmentation based on artificial neural network

A neural network is an artificial representation of human brain that is used to simulate its learning process. An artificial neural network is often known as a neural network [22].

Now days, artificial neural networks have been widely used to solve the problem of medical image segmentation. Neural network is based on simulation of life; especially the human brain's learning process constitutes a large number of parallel nodes. Each node can perform some basic computing. The learning process can be gained by transferring the connections among nodes and connection weights [15]. Its main advantage is that it is independent on the probability density distribution function. It can also prove the segmentation results when the data deviation occurs from the normal situation. Neural network also reduce the requirements of expert intervention during an image segmentation process. This problem is dominant over many image segmentation methods. Firstly, the image segmentation problem is converted into classification issues. Then the issues are solved based on neural network. The neural network is trained with training sample set in order to determine the connection and weights between the nodes. Then the new images are

segmented with trained neural network. Neural network segmentation method consists of two important steps: feature extraction and image segmentation based on neural network.

TABLE 1 COMPARISON OF IMAGE SEGMENTATION TECHNIQUES

Region Based Technique	It groups pixel into homogeneous regions including region growing, region splitting, region merging or their combination.	1) Computationally inexpensive. 2) Fast and simpler to implement. 3) Can work in real-time applications	1) Are by nature segmentation sequential and quite expensive. 2) Region grow -ing depends on the selection of seed region and the order in which pixels and regions are examined.
Fuzzy Technique	In it fuzzy operators, properties, mathematics, and inference rules are applied which handle the uncertainty inherent in a variety of problems due to ambiguity rather than randomness.	Fuzzy members- -hip function can be used to represent the degree of some properties or linguistic phrase. Fuzzy IF THAN rules can be used to perform approximate inference.	1) The determination of fuzzy membership is not a trivial job. 2) The computation involved in fuzzy approaches could be intensive.
Neural Network Technique	Using neural networks to perform classification or clustering.	No need to write complicated programs. Can fully utilize the parallel nature of neural networks.	1) Training time is long. 2) Initialization may affect the result. 3) Over training should be avoided.

	Method Description	**Advantages**	**Disadvantages**
Edge Detection Technique	It is based on the detection of inhomogeneity, generally tries to trace points with more or less abrupt changes in gray level.	Edge detect-ion technique is the way in which human understand the objects and works well for images having good contrast between regions.	1) It does not fit well for images in which the edges are ill-defined or there are too many edges. 2) It is not a tedious task to generate a closed curve or boundary. 3) Performance is affected by the presence of noise.
Thresholding Technique	It requires that the histogram of an image has a number of peaks; each of it's corresponds to a region.	It works well when the region homogeneity criterion is easy to define. They are also more immune to noise than edge detection approach.	1) Neglects the spatial information of the image. 2) Highly noise sensitive. 3) It does not work well for an image without any obvious peaks or with broad and flat valleys

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III. CONCLUSION

In this review paper, the various image segmentation methodologies applied for digital image processing is explained briefly. These methods are most important for detection of pattern and recognition using edges, images and points. Image segmentation is used in medical science to identify the region of interest i.e. locate tumor, lesions and other abnormalities from medical images. They also detect roads and features from satellite images. The last section of this paper shows the comparison between various segmentation techniques.

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