STUDY OF IMAGE SEGMENTATION TECHNIQUES

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Abstract : Image segmentation breaks down the image into meaningful regions. It is an important phase in Digital Image Processing as it differentiates between the objects which are to be inspected further and the other objects or their background. This paper presents different approaches which can be used in Image segmentation. Various existing segmentation techniques like K Means, Image segmentation using Arithmetic mean, Image segmentation using Entropy and Histogram, Segmentation using between Cluster Variance and Image Segmentation via Genetic Algorithms have also been discussed where Genetic Algorithms based Image segmentation technique was proved efficient.

***IndexTerms* – Image Segmentation, Genetic Algorithms, Image Segmentation Techniques.**

I. INTRODUCTION

Image Segmentation is the process of dividing an image into a set of regions according to pixel properties like color, gray level values, intensity values etc [1]. The output of image segmentation are finite distinct segments which cover entire image. Segmentation plays an important role in Image Analysis Process. Image Segmentation represents the meaningful areas of the image by segregating the relevant part of image from irrelevant ones [2]. The detection of meaningful and required areas of image may prove helpful in their future inspection. The two objects of Image segmentation are breaking down an image into regions and to perform a change in representation to make it more meaningful or efficient for analysis. Major applications of Image segmentation includes Medical Imaging (Identification of tumors and pathogens), Machine vision, Object detection and Recognition tasks (Face recognition, fingerprint recognition) [3].

The organization of the paper is as follows, Section II discusses Image Segmentation Approaches, section III discusses Brief history of Image Segmentation, section IV presents Image segmentation Techniques and section V concludes.

II. IMAGE SEGMENTATION APPROACHES

There are many approaches in which segmentation techniques can be classified. Some of them are Threshold method, Edge based techniques, Region based approaches, Clustering, Watershed based methods, ANN based approaches etc. These are illustrated in the following diagram.

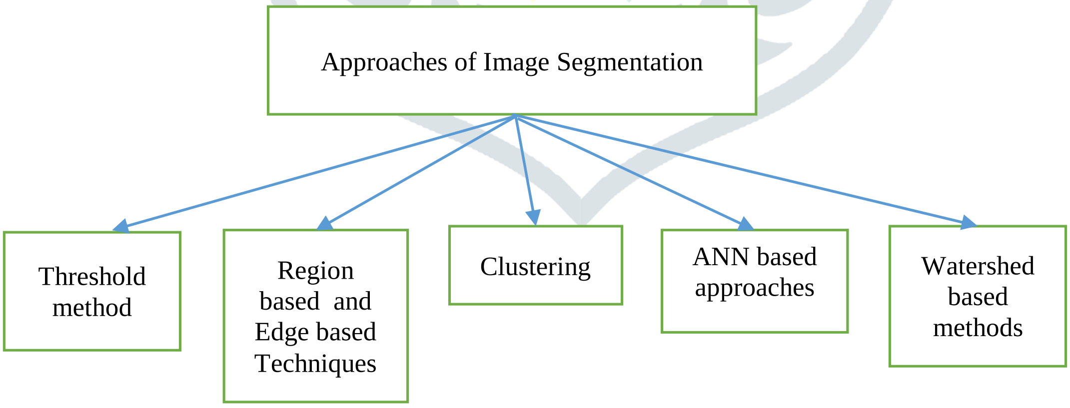

Figure 1: Image segmentation approaches

1. Thresholding Method: These are the simplest methods which are used for image segmentation. In this method, segmentation is performed based on intensity values of pixels [4]. Generally a threshold value T is selected and with chosen threshold segmentation is done. For a given image p(x,y), let o(x,y) be the segmented image.

$$o(x,y) = \begin{cases} 1, & if\ p(x,y) \geq T \\ 0, & if\ p(x,y) < T \end{cases} \quad \text{Eq. 1}$$

2. Region based techniques: The given image is segmented on the basis of common patterns in intensity values of pixels i.e. the neighbouring pixels having some sort of similarity in intensity values are grouped together within a region [5]. The output of Region based techniques are finite distinct set of regions which cover the entire image.

3. Edge based techniques: Here sudden changes in the objects present in the image are identified so as to highlight their boundaries. With these techniques different objects present in the image can be accurately distinguished. Gray histograms and Gradient based methods are common edge based image segmentation techniques [5]. The most popular edge detection techniques are Sobel operator, Canny operator and Robert's operator.

4. Clustering: Clustering is a process of classifying the pixels into various clusters such that intra-cluster similarity is more than inter-cluster similarity. Classification is done on the basis of pixel similarities [6].Hierarchical method and Partition based method are common categories of clustering.

5. ANN based approaches: ANN based segmentation techniques replicates the learning strategies of a human brain for decision making [6]. A NN is an Artificial Intelligence (AI) system which is inspired by the biological nervous system [7]. It can imitate the working of a human brain and can be used for performing various computational tasks more efficiently as compared to a human brain [8]. It can be used to partition required part of image from its background.

6. Watershed based methods: These methods utilizes the concept of topological interpretation. Here some basins are present which have hole in its minima. Water spills from the hole and intensity represents the basins. Adjacent basins are combined whenever water reaches border of basins [6]. Dams are generated in order to separate basins. These dams provide borders for segmenting the image.

III. HISTORY OF IMAGE SEGMENTATION

Image segmentation research has experienced three periods of extensive activity. The first peak in image segmentation was experienced in 1960s due to the introduction of Roberts edge detector by Lawrence Roberts [9]. The second period of extensive research in image segmentation was performed by Brice and Fenema in early 1970s along with the research by Pavlidis in 1072 [9]. Since early 1970s, Image segmentation has received considerable renewed interest. The beginning of 1985 to the end of 1989 was some crucial years which led to the development of image segmentation techniques [9].The third occurrence was identified in 2001, when Yu-Jin Zhang discovered that there was quick evolution in the area of image segmentation [10]. Apart from these, many other developments were made like the introduction of Snake theory by Kass. M. et. al. in 1987, Geodesic Snakes model by Caselles V. et. al. in 1995 and Yu-Jin Zhang's discovery in 2009 [9]. Yu-Jin Zhang has provided a detailed historical events of Image segmentation in the year 2009 [10].

Table 1 describes history of Image segmentation in brief.

Table 1. History Table

Year of Publication	Author	Discovery	Purpose
1965	Lawrence Roberts	Presented first ever edge detector. It was initially used for partitioning the components of the image.	It was introduced to detect edges of objects present in image.
1970	Brice and Fenema	A novel approach was proposed in which segmentation was performed on the basis of selected threshold. Ratio of length of weaker part to its length is computed.	If the computed ratio is greater than selected threshold, then Ωi and Ω_j are to be merged.
1972	Pavlidis	In the proposed model all the pixel are initially taken as individual regions. Then for every pair of regions, Variance was calculated and hence segmentation is performed.	The approach was an extension to the model of Brice and Fenema.
1985-1989	Mumford shah	In the work result of segmentation of an image I_o came out as a pair (∂Ω, I), where I represents some approximation of I_o. I_o is defined in Ω.	The foundation of Image segmentation as the formalization of region growing was done in this phase.
1987	Caselles V. et. al.	The work introduces a model where contours of an object can be identified automatically.	A new Energy Function was suggested in this work.
1995	Morel, Solimini	A novel approach was proposed where threshold value was used for performing segmentation.	This model resolved the drawbacks of Pavlidis approach (1972).
1995	Caselles V. et. al.	This work presented a Geodesic Snakes Model. An Energy function was also suggested.	The proposed Energy function is intrinsic criteria.

1998	Aubert and Blanc Ferraud	In this work the Energy function proposed by Caselles V. et. al. in 1987 and the one presented by Caselles V. et. al were reviewed.	It was analyzed that the reviewed energy functions were equivalent.
2001	Yu-Jin Zhang	This work identified that there was quick evolution in the area of image segmentation.	Great changes were made to the concept of Image segmentation during this period.

IV. IMAGE SEGMENTATION TECHNIQUES

In this subsection, some existing segmentation techniques of image segmentation are described:

4.1 K Means:

K Means is one of the most commonly used partitioning methods for clustering. In this, K clusters c1, c2--ck are present with respective means m1, m2--mk which measures closeness of the data from their assigned clusters [11]. A least-squares clustering procedure inspects all the possible partitions into K clusters and select the one with which D can be minimized. Due to computational infeasibility, the popular methods used are approximations. One major issue of this method is the requirement of knowing K prior to the execution [6]. If K is not known, this approach cannot be used. Many algorithms demand K as an input from the users and some seek to find appropriate K according to some criterion which can include maintaining the variance of each cluster smaller than the specified value. Algorithm for K means is shown in Figure 2.

Algorithm

1. Randomly K data items are chosen from data set X as initial centers.
2. Repeat
   a. Calculate the Euclidean distance between each data point and chosen cluster centroids. The data point is assigned to the cluster whose cluster centroid is closest to it. Euclidean Distance can be calculated as-

   $$D(\mathrm{c_k}) = \sum_{\mathrm{x_i} \in \mathrm{c_k}} ||\,\mathrm{x_i} - \mathrm{c_k}\,||^2$$

   b. Calculate new cluster centers by taking mean of the data points present in each cluster.

   The process is repeated until the convergence criterion is satisfied. Convergence criteria for K Means is -

   $$C_k(i) = C_k(i+1) \text{ for all k}$$

Figure 2: Basic K Means Algorithm

The process of K Means will stop when there is no change in clusters i.e. when the data points present in k clusters in ith iteration is equal to the data points present in k clusters in (i+1)th iteration.

4.2 Image Segmentation using Arithmetic Mean:

An important statistical feature is mathematical expectation of random variable [4]. It uses the average value of random variables which are similar to objects center of mass. So dividing images according to the gray-level center should be the best point of balance [4]. If it is a colored image, then it must be converted first into gray scale image by using rgb2gray inbuilt function. The mathematical expectation of a gray image can be determined by the following equation:

$$\mu_{\text{threshold}} = \sum_{n=1}^{N} \mathrm{L_n P(L_n)} \qquad \text{Eq. 2}$$

Where
Ln= nth gray-level of image
P(Ln)= Probability of Ln
Threshold is used for dividing the image into distinct regions.

$$\text{Value} = \begin{cases} 1, & if(img[i] \geq threshold) \\ 0, & otherwise \end{cases} \qquad \text{Eq. 3}$$

4.3 Image Segmentation using Entropy and Histogram:

Whenever a histogram is created of a gray level image, where there is a significant difference in the gray-level distributions of foreground and background, two peaks may be seen. In this case the more appropriate trough is chosen as preferable threshold. In other words threshold can be used to distinguish different gray-level distributions of foreground and background of an image. However the presence of noise or an uneven gray-level distribution may result in some unwanted troughs in the histogram which prevents us to obtain a reasonable threshold. It is a burdensome task to detect an ideal threshold as the trough is observed manually from the histogram [12].

Entropy is a statistical property of images which measures the image information content. Entropy determines the status of segmentation i.e. greater the entropy of a segmented image, more information can be obtained through it [12]. If more troughs are present in the histogram, then each trough is selected as a threshold and for each threshold, entropy is calculated. The segmented image having maximum entropy is selected and its corresponding threshold is chosen.

The image entropy can be computed as

$$H(S) = -p_1 \ln(p_1) - p_0 \ln(p_0) \qquad \text{Eq. 4}$$

Where
H(S) = Image Entropy
P1= Probability of 1 in segmented image
P0= Probability of 0 in segmented image

4.4 Image Segmentation using maximum between Cluster Variance

Variance is a measure that determines homogeneity of an image having gray scale distribution. Higher the variance, difference between object and background is more. Whenever pixels of object are merged with that of background by mistake, difference between object and background will be minimized and vice-versa. In other words there are less chances of mistake in segmentation whenever image segmentation is done using maximum between cluster variance [12]. For a gray-scale image, let T be the threshold ranging from minimum gray-level value to maximum gray-level value i.e. (0-255). The between cluster variance can be calculated as:

$$\sigma^2(T) = W_A(\mu_A - \mu)^2 + W_B(\mu_B - \mu)^2 \qquad \text{Eq. 5}$$

Where
WA = ratio of number of pixels in object to total pixels present in image
μA = average of pixels in object in gray-level
WB = ratio of number of pixels in background to total pixels present in image
μB = average of pixels in gray-level
μ = average of gray-level pixels present in whole image.
The threshold is considered best whenever between cluster variance of object and background is maximum.

4.5 Image Segmentation via Genetic Algorithms

A Genetic Algorithm (GA) is a metaheuristic technique which is inspired by the process of natural selection that belongs to the larger class of Evolutionary Algorithms (EA) [13]. It is an iterative process where each iteration yields new generation. It is an evolutionary algorithm which generates good quality optimum solution for complex problems. In the paper "Image Segmentation via Genetic Algorithms" [14], a GA based technique has been proposed where the process starts by initializing start population randomly where chromosomes are the combination of 1s and 0s. Size of each candidate chromosome is (n*m). Entropy of each candidate chromosome can be calculated as-

$$\text{Entropy}(\lambda) = \sum_{n=1}^{N} [-P(L_n) * \ln P(L_n)] \qquad \text{Eq. 6}$$

Where
Ln = nth gray level of image
〖P(Ln) = Probability of Ln
Fitness Function is based on entropy of chromosomes. It is computed as-

$$\text{Fitness Function} = \frac{1}{1+e^{-\lambda f}} \qquad \text{Eq. 7}$$

Where
f = Entropy of segmented image
λ = Constant value proportional to entropy (f)

The Fitness values of candidate chromosomes are calculated. Following process is repeated till stop conditions are not satisfied [15].

1. Fittest chromosomes i.e. chromosomes with highest fitness values are picked using roulette Wheel Selection method.
2. Selected chromosomes undergo crossover and mutation.
3. Modified offsprings are inserted into population
4. If stop criteria is not satisfied then go to step 1. Else the fittest chromosomes from the last generation are returned as solution.

The process will halt if any of the following stop criteria is satisfied-

a) When there is no further improvement in population i.e. the chromosomes present in the ith generation are same as the ones present in (i+1)th generation [16].
b) When the specified number of generations is reached [17].

The chromosomes present in the last generations are fittest i.e. they have highest fitness values. Maximum fitness value indicates higher entropy. Greater the entropy of an image, more information can be retrieved from it [18]. The selection of chromosomes from last generation is done randomly. From the chosen chromosome, segmentation is performed.

V. CONCLUSION

This paper discusses some existing Image Segmentation techniques. K means is simplest technique but its major issue is the requirement of knowing K prior to the start of execution. Also it has a tendency to stuck in local minima. Image segmentation using Arithmetic mean method provides average of pixels present in an image and calculates a threshold from it. The threshold is used for segmentation. Since segmentation is purely based on threshold, it is important to calculate it carefully as an incorrect threshold may result in poor segmentation. Also it cannot be used in case of missing values. Image segmentation using Entropy and histogram may result in unwanted troughs in histogram due to presence of noise in the image. GA based Image segmentation techniques resolves all the drawbacks stated above and provides promising results. This paper discusses some existing Image Segmentation techniques. K means is simplest technique but its major issue is the requirement of knowing K prior to the start of execution. Also it has a tendency to stuck in local minima. Image segmentation using Arithmetic mean method provides average of pixels present in an image and calculates a threshold from it. The threshold is used for segmentation. Since segmentation is purely based on threshold, it is important to calculate it carefully as an incorrect threshold may result in poor segmentation. Also it cannot be used in case of missing values. Image segmentation using Entropy and histogram may result in unwanted troughs in histogram due to presence of noise in the image. GA based Image segmentation techniques resolves all the drawbacks stated above and provides promising results.

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