A Survey on Image segmentation algorithms
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Abstract
The applications in image processing like image recognition or compression, the process cannot be done directly due to its inefficiency and practical problems. Hence, some of image segmentation algorithms were introduced to segment an image. Image segmentation is a process of splitting or partitioning an image into multiple numbers of segments that is pixels otherwise known as superpixels. The splitting up of an image into meaningful object is with respect to the similar characteristics like color, intensity, texture etc. Till now various number of image segmentation algorithms were proposed and were applied in our day-to-day life. In general, image segmentation algorithms can be categorized into region-based segmentation, edge-based segmentation, feature based clustering segmentation, threshold based segmentation, graph based segmentation and model based segmentation. The main objective of image segmentation algorithms is to preserve the features of an image with improved efficiency and reduced computational time. We analyze some of the segmentation methodologies that aim at giving better efficiency.

Keywords: Image Segmentation, Region Growing, Cluster Centroids, Genetic Algorithm.

I. Introduction
Image processing is a process which converts a digital image or video into either an image or a set of characteristics or may be a parameters related to an image. For the conversion of images into various features and parameters, it uses the concepts like image segmentation, image acquisition, image restoration, image segmentation, image measurement etc.

Among the image processing techniques, image segmentation acts as major role in various applications. Image segmentation algorithms are generally categorized into:
1. Region based segmentation
2. Feature based clustering segmentation
3. Edge based segmentation
4. Model based segmentation
5. Threshold based segmentation

Region based segmentation
The basic principle of region based segmentation is to compare the pixels with its neighborhood having the similar values. If the similarity criterion is satisfied, the pixel is assumed to be the clusters tone or more of its neighbor. The segmentation algorithm is quite efficient for noise affected images too. The major four algorithms used for region based segmentation are seeded region growing, unseeded region growing, region splitting and merging technique and fast scanning method. The seeded growing algorithm is a simplest method in which it evaluates the seed points and analyze whether the other neighboring pixels can be clustered to the seed or not[1]. The unseeded region growing algorithm[2] is derivative approach of seeded growing algorithm where the selection of seed point is generated automatically. The main advantage of unseeded region growing algorithm is its robustness towards a noise affected images where the segmentation process is highly efficient with less computational complexity. In region splitting and merging technique[3], quadtree is used as the basic concept to identify the homogeneity of the image. A Quadtree is a tree like representation in which the root represents the image and each node of the tree has four descendants. The fast scanning algorithm[4]-[8] is direct opposite to region growing method, where it does not require any seed point calculation. Instead it start scans the entire image from upper left towards the lower right corner and merge the pixels to its nearest clusters based on the threshold values.

Feature based clustering segmentation
Image segmentation can also be done on the feature based clustering method very efficiently. Clustering is a process of using centroid concept for each cluster and based on the similarity, it classify the remaining pixels on the histogram. Clustering concept [9] –[12] combines partitioning and grouping method, which can be broadly classified into hierarchical and partitional clustering. The basic concept of hierarchical clustering is to construct a group of patterns of an image. The hierarchical clustering method is divided into two types of algorithms namely hierarchical agglomerative algorithm and hierarchical divisive algorithm. The partitional clustering method includes the algorithms such as Squared error algorithm, k-means algorithm, improved k-means algorithm, C-means algorithm, Fuzzy C-means algorithm[13] –[20] and mean shift algorithm. The Genetic algorithm[21] –[23] is applied to get the best optimization results in
clustering techniques. The k-means algorithm is the most widely used clustering techniques due to its easy implementation and reduced complexities. To enhance the efficiency, the k-means algorithm is improved by combined the concept of threshold techniques[20]. The mean shift algorithm works on the basis of density estimation where the feature space is considered for the calculation.

**Edge based Segmentation**

To identify the boundary region of an image, the edge based segmentation method is used. The edges were identified by using fixed and adaptive feature of support vector machine.[24] Before the segmentation process, some of the edge detection methods such as gradient operators[25], Hilbert transform [26] and Canny edge detector were used. The edge based segmentation is categorised into sequential edge detection and parallel edge detection. Apart from these methods, to identify only the edges (peaks), the watershed segmentation algorithm is used effectively.

**Model based segmentation**

In model based segmentation, to identify the edges of an image accurately, Markov Random Field (MRF) [27] method combined with edge detection method is applied. In MRF method, it has spatial region smoothen constraint for color image segmentation. The model based segmentation can also be achieved by using Gaussian Markov Random field (GMRF)[28] with the region growing concept[29].

**Threshold based segmentation**

It is the easiest method of segmentation where the threshold values obtained from histograms[30] are used for segmentation process. It has very less computations when compared to other segmentation methods. The main drawback is not able to apply for complex images.

Survey of some of the segmentation algorithms is represented in section 2 to section 6 and a comparison chart for the same in section 7.

II. RELATED WORKS

2.1 Region-based segmentation-Least Square Method (LSM) [5]

Image segmentation is a process of partitioning an image into set of regions (pixels, or superpixels), which uses a most popular method Active Contour model [6]. This method applies the category of both edge-based and region based segmentation.

In an edge based method, to detect the image boundaries, the image gradient is used. The major drawback of this method is sensitive to noisy images and highly depends on curve placement.

When compared to the edge-based method, region-based method is very less sensitive to the effect of noise images. Also it does not utilize the gradients for boundary detection and at the same time it yields better performance in image segmentation. For the region based segmentation many models has been proposed. Mumfort-shah energy function, Chan-Vese model[7], Otsu’s method[8], but with the limitations of slow converging and high error function. Hence, a region based model with weight matrix based on Least Square Method is proposed to minimize the error function.

2.1.1 Least Square Method (LSM)

Least square method is a problem of finding a vertex that is a local minimize to a function, subject to some constraints. It can be applied either to a simple linear regression, multiple linear regression or with non linear model.

**Steps to be followed in a simple linear regression**

Step 1: Let the variables Y is assumed to be the response variable or dependent variable and X be the auxiliary or independent variable. Let the parameters be assumed as A and B.

Step 2: The response variable Y is calculated as Y=A+BX.

The main objective of LSM is to estimate the parameters based on the observed pair of values and then the criterion function is applied. The main advantage of using Least Square method is to minimize the squared error between the data.

2.2 Improving Clustering Algorithm with Density and Distance (ICADD) [9]

In K-means clustering technique of unsupervised algorithm [10] with threshold technique, clusters have been grouped based on the similarity between the pixels. Here the cluster number has to be given in prior.

Similarly, in the unsupervised learning algorithm of Fuzzy- C-Means (FCM) technique[11], [13], it clusters the data by calculating the distance between the pixels and the cluster center. Here again the cluster number to be provided in prior.

Hence, this paper proposed a Density Peak(DP) clustering algorithm to determine the cluster number and cluster center based on the decision graph. DP cluster algorithm is used to calculate the distance and density without the prior knowledge of cluster number.

**Steps followed in DP clustering algorithm**

Step 1: Transformation: The original image is transformed into three color channels.

Step 2: Apply Density Peak clustering algorithm[12].

  a. Compute the distance and density by using Euclidean distance as the basic measurement of data distance and Gaussian kernel for density.
b. Plot the decision graph with distance and density values to identify the cluster centers, clusters with high density and larger distance.

c. Identify the cluster numbers.

Step 3: Add the remaining points to the clusters for image segmentation.

Step 4: Repeat the above steps until all the labels are marked.

The proposed DP clustering algorithm used the most popular Berkeley image database for the experimental results.

**Advantage:**

1. To identify the cluster centers and numbers, decision graph is used instead of prior knowledge.
2. With this algorithm, the hierarchical segmentation is easily achieved.
3. It act as a good processing method for the operations like pattern recognition and image segmentation annotation.

**Limitations:**

1. Instead of providing the cutoff distance in prior, the algorithm is modified by selecting the values automatically based on the input image itself.

2.3 Adaptive Unsupervised Clustering Approach (AUCA) [13]

The main objective of this paper is to improve the clustering quality with classification error reduction. To achieve this objective, two main module is proposed: Region splitting and Merging and Fuzzy-C-Means clustering technique.

**Steps followed in AUCA**

**Step 1:** Input a color image with RGB representation.

**Step 2:** Region Splitting and Merging module (RSM)

To identify the cluster centers and numbers, two techniques were applied:

a. Histogram thresholding technique [14]: Detect the peaks and valleys in the histogram of all multiple homogeneous region by image decomposition.

b. Merging technique: It is applied for merging the homogeneous regions to obtain the cluster centroids and numbers. To calculate the cluster distance, Manhattan distance is used instead of Euclidean distance.

**Step 3:** Fuzzy –C- Means Clustering (FCM)

The main objective of FCM clustering technique developed by Dunn [15] and improved by Bezdek [20] is to partition each image pixel into a collection of fuzzy cluster centers. FCM is applied iteratively to minimize the objective function. To terminate the criterion function, the threshold value is fixed with a small positive number between [0,1]. To calculate the cluster quality, Mean Square Error (MSM) is used in this method.

**Advantage:**

1. Combined RSM and FCM technique leads to better segmentation when compared with other techniques like, Ant system, Ant Colony Fuzzy-C-Means Hybrid algorithm and Agglomerated Just Noticeable Difference Histogram.
2. The cluster center and the number is determined automatically using RSM technique.
3. With the concept of fuzzy C-mean, the classification error is reduced.

2.4 Improved Fuzzy C Means algorithm (IFCMA) [16]

The most popular clustering methods like Fuzzy C-Mean[15] and [20] the improved techniques like FLICM [17] are not appropriate for the better segmentation with the corrupted images like noise, imaging artifacts, etc. Since these algorithms takes only the gray values of pixels. Hence an improved Fuzzy-C-Means algorithm along with local spatial information and gray level information with reduced fuzzy constraint factor is proposed to obtain better segmentation with robustness to noise. Inorder to calculate the distance between the pixels, Euclidean distance is used here.

**Steps Followed:**

**Step 1:** Initialize the amount of fuzziness, Euclidean distance and the number of clusters.

**Step 2:** Initialize the cluster center using Euclidean distance and calculate the membership matrix.

**Step 3:** As per the values obtained in matrix, update the clustering center.

**Step 4:** Repeat the steps iteratively until the matrix values is less than the Euclidean distance.

**Advantage**

1. When compared to FLICM[17] algorithm, the proposed algorithm preserves the image features.
2. Also the running time reduced when compared to FLICM[17].
3. It consider both the gray level as well as spatial information by local minimum value.
4. It improves the performance of image segmentation of images which is affected by noise, airtfacts, etc.

2.5 Genetic + Fuzzy C means algorithm (G+FCM) [21]

To optimize the evaluation function, the Genetic Algorithm is proposed. It control the
splitting and merging of regions in an image. Here the K-means clustering technique is applied to produce the initial population for the GA which acts as a seed chromosome.

In order to preserve the edge information, a fuzzy based edge-boundary coincidence measure is combined with heterogeneity measure. When combining the image segmentation techniques like, Genetic algorithm, Fuzzy set, K-means clustering, etc the characteristics like evaluation criterion, mutation can be achieved with high efficiency. Also it reduces the search space of the Genetic algorithm.

Steps followed:
Genetic Algorithm is an iterative procedure applied for optimal solution, where the crossover, mutation, chromosomes with better fitness were obtained.

Step1: An initial population is created which is used as the seed chromosome to evaluate the fitness function.
Step 2: Increase the population by a two-point crossover operator [22] and generate two offsprings.
Step 3: Mutation process of splitting and merging is applied to the newly generated offspring and the fitness values are computed.
Step 4: Repeat the steps 1 to 3 until the entire population of individuals is generated.
Step 5: At the termination criteria, find out the individual with best fitness value.

The fuzzy-set based evaluation function is obtained by edge operator[23] and the member function is applied for multi-band images.

### III. Comparison Chart

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<tbody>
<tr>
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<td>Feature based clustering segmentation</td>
<td>Feature based clustering segmentation</td>
<td>Feature based clustering segmentation</td>
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<td>Density Peak Clustering method</td>
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<tr>
<td>Type of data set</td>
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<td>Berkeley data set</td>
<td>Real images</td>
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<td>Real images</td>
</tr>
<tr>
<td>Threshold</td>
<td>Not considered</td>
<td>Till the neighbour pixels are clustered</td>
<td>Small positive number between [0,1]</td>
<td>Till the neighbour pixels are clustered</td>
<td>Until the entire population of individuals is generated</td>
</tr>
<tr>
<td>Noise affected image</td>
<td>High efficiency</td>
<td>Less efficiency</td>
<td>Not considered</td>
<td>High efficiency</td>
<td>Not considered</td>
</tr>
<tr>
<td>Computational time</td>
<td>Less computational time</td>
<td>High computation time</td>
<td>Less computational time</td>
<td>Less computational time</td>
<td>Reduces search space in Genetic Algorithm. Less computational time</td>
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<td>For pattern recognition and image segmentation</td>
<td>Classification error is reduced</td>
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<td>Membership matrix is used</td>
<td>Edge operator is used for evaluation function</td>
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In the above table, the following acronyms have been used:

- **LSM** = Least Square Method
- **ICADD** = Improving Clustering Algorithm with Density and Distance
- **AUCA** = Adaptive Unsupervised Clustering Approach
- **IFCMA** = Improved Fuzzy C Means algorithm
- **G+FCM** = Genetic + Fuzzy C means algorithm

### IV. Conclusion

Gang Chen, Tai Hu, Xiaoyong Guo, Xin Meng [5] proposed the region based least square
method to minimize the error function. The proposed method is best suitable for all noise affected images and image artifacts. It uses both local and global information and it is used for real time image processing. The method produces an optimal solution with more accurate and effectiveness.


References

Region-based


Feature based


[13] K. S. Tan, N. A. M. Isa,W. H. Lim[13] used both Region Splitting and merging technique and Fuzzy C-means clustering to provide more homogeneous segmented regions and also to minimize the classification error. When RSM is used, it does not guarantee the optimum final cluster centers. Hence FCM is added to provide better segmentation.

Xueang Hu, Lei Li[16] improved the Fuzzy C-Means algorithm by modifying the fuzzy factor of FLICM method. The proposed algorithm reserves the image details with less computational time.

Xiaoying Jin, and Curt H. Davis [21] combines the genetic based along with fuzzy set theory to improve the performance of the segmentation. This function provides a parameter-free way to combine the edge and region information.

Models based


Threshold based