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Comparative study for analyzing image segmentation algorithms

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ABSTRACT
Segmentation is an important way to extract and specify interested region from complex images. Currently there are number of algorithms which can be used for segmentation and analysis of complex images. In this work, we have studied various segmentation algorithms- Edge Detection, Thresholding, Region Growing, K- Means and Fuzzy C-Means algorithm and compared them to find the most suitable candidate which can provide optimum results in terms of segmentation efficiency and accuracy. The real objective is to shortlist an algorithm for evaluating the suitability in further research of performance analysis in segmentation and processing of complex images.

Keywords **-** Fuzzy C-Means, K-Means, Comparison, Segmentation, Parallel Techniques .

I. INTRODUCTION

Image Segmentation is generally enhancing the granular information in images for viewers and offering improved input for different automated image processing techniques. The primary aim of segmenting an image is to enhance quality and suitability for presenting the image for a specific given task in front of an observer. Clustering or segmentation is a process of partitioning of color or grey scale image into various set of segments. The major benefit of Image segmentation is to provide a convenient way of image representation and analysis. In this process, whole image is distributed and categorized in to different group of image sectors. These sectors consist of similar image level on a pixel basis. Thus, displaying same level pixels prominent and making the image outlines brighter which can be used for further analysis. Application of image segmentation is vast and could be used in many fields. It enhances clarity in the algorithms and innovating new methods of analysis is interested region and supports better object recognition. [1] There are number of various image segmentation algorithms which are currently used and applied for different purposes. The idea of optimizing these still a widely open research area. The optimal way of deriving better techniques is to combine suitable algorithms within specific domain. It is always challenging for researchers to decrease the computation time for segmenting complex image structures. The selection of parameters and the distribution of image level depend upon the specific task and its application. [2]

II. LITERATURE SURVEY

TMorphological closing is achieved by thinning the edges to unity width in morphological edge detection algorithm. It is very problematic to form close boundaries from spatially separated edge segments. If the edges remain unclosed, segmentation of an image cannot be defined.

The region growing algorithm is not the best as it has produced an almost inferior result due to the outcome of various labels which separate non-convex regions even when they have common similarities.

In FCM algorithm, there are well defined clusters that echo good behavior in image segmentation. In FCM algorithm, the image is divided and clubbed in fuzzy partitions that increase descriptiveness by only using pixel intensity characteristic. [5]

Other algorithms often imply possibilistic clustering as it is done in the case of 1-D data, but they fail to draw specific difference in the cluster boundaries. On the contrary, the approach of defining irregular shape of fuzzy sets eventually slows down the overall convergence in the system as used in FCM algorithm. FCM algorithm can be iterated to determine the exact numbers of clusters needed to make the system autonomous. FCM is iterated for a range of hypothesized number of clusters and selecting the best alternative on the basis of measuring cluster validity. [6]

The optimal tradeoff between localization performance and detection can be achieved by developing optimal edge detectors and more research on edge detection. There must be a thought given for three important criteria: good detection, optimal localization, and unique response to individual edge on the basis of which best approach can be followed for designing good edge operators.[7]

The self –adaptive threshold consists of a limitation of producing only single threshold, which proves difficult to extract the required image information. Therefore, a new segmentation algorithm is proposed which can have its own threshold via calculating statistical information of the gray scale values of its neighborhood pixels on the basis of image level. [8]

The image is divided in to three classes which are based on two class means derived by clustering. The three classes are categorized as the foreground with pixel values are greater than the larger mean, the background with pixel values are less than the smaller mean, and especially, a third class which we call the to-be-determined (TBD) region where pixel values fall between the two class means. [9]

It is obvious that region growing algorithms seem to be dependent at the point where the growing process starts in an image i.e. the point at orientation of Region of interest in the image. This dependency suggests that a partitioned outcome is sensitive to the selection of seeds which are initial growing points. As the segmentation process continues, the measured feature information adaptively transforms and this creates a problem. Most seeded region growing processes add a new point to a region if its corresponding feature measures are identical to those of an adjacent existing region. After addition of this new point to the region, the feature measure of the region gets modified. Thus, different initial growing point assignments finally lead to different values for evolving region information [10]

In image segmentation, clustering proves to be a very powerful tool. Image data set is partitioned in to various disjoint clusters or groups and this is often known as cluster analysis. There are many proposed algorithms for image segmentation like k means, improved k mean, fuzzy c mean (FCM) and improved fuzzy c mean algorithm (IFCM). K-Means clustering is one of the popular algorithms available from various options as it provides simplicity and computational efficiency. Improved K compare is one way ahead from conventional K means since a reduction in the overall number of iterations. FCM algorithm has more flexibility for the pixels to belong to multiple fuzzy classes with varying degrees of membership. [11]

The ultimate goal of implementing various image segmentation algorithms is to achieve better and efficient segmentation. K-means algorithm is used in number of applications and is found in most of the research. In the K-mean (KM) algorithm, a large set of pattern is grouped into disjoint and homogeneous clusters, and each and every cluster is characterized by its center point. However, KM algorithm suffers from several drawbacks; such as its sensitivity to initialization, which could lead to poor segmentation and convergence to local optimal location.

To overcome the aforementioned disadvantages, a flexible and membership based clustering algorithm - Fuzzy C means (FCM) is proposed by Dunn, which was later generalized by Bezdek. In Fuzzy C-means, each point has a degree of membership to all

clusters rather than completely belonging to a single cluster. The cluster is the mean of all points, weighted by their degree of belonging to the cluster.

This property is responsible for making FCM less sensitive to initialization and therefore could segment the data into appropriate clusters with less intra cluster variance. However, it might also converge to local optimum location. [12]

III. PROBLEM FORMULATION

The paper aims to analyze the performance of image segmentation. The desired outcome is to analyze the conclusions regarding image segmentation using different algorithm comparison.

The focus is to create and attain Data & algorithm comparison and then showing the speedup of processing image segmentation. After performance analysis, a conclusion would be extracted which can be inferred for further application. Suitable future directions will be identified and drawn considering limitations of existing work.

The main Objective of the paper is to analyze the performance of image segmentation algorithm.

1. Edge based segmentation –Segmentation is achieved by opening and closing operation i.e. Erosion (shrinking) & Dilation (expansion). The edges and region boundaries are closely associated (related). This is due to the often sharp adjustment in intensity at the region boundaries.

- Facts - There is often a case of disconnect between the detected edges. To identify and segment an object from an image however, closed region boundaries are required. The desired edges are the boundaries between such objects. Therefore the segmentation methods can also be applied to edges obtained from edge detectors. [14]
- Major Drawbacks -

1. It does not work well on images with smooth transitions and low contrast sensitivity to noise.
2. In this method, robust edge linking is not trivial.[15]

2. Threshold based segmentation – In this algorithm, the threshold of a pixel in an image is estimated by calculating the mean of the grayscale values of its neighbor pixels, and the

- Major Drawbacks –

1. It lacks the sensitivity and specificity needed for accurate classification and it is difficult to define functional and statistical measures only on the basis of gray level value (histogram).
2. The problem gets severe in case of multi-modal histograms with no sharp or well-defined boundaries.

3.Region growing- This method is a collection of pixels with similar properties to form a region. It recommends finding a seed pixel as a starting point and then merging the same or similar property of pixel.

- Facts - This technique accepts a set of seeds as input along with the image. The seeds notify each of the objects to be segmented. All unallocated neighboring pixels to the regions are compared to iteratively grow the region. The pixel with the smallest difference measured in respect of similarity is allocated to the respective region. The process is recursively iterated until all pixels are allocated to a region. [17]

- Major Drawbacks -

1. This is not trivial to find good starting points.
2. There is a requirement of good criteria for similarity.
3. Seeds are required as additional input for region growing.
4. There is a possibility of poor placement of seeds due to the noise in the image. [18]

4. K-means – Clustering is an unsupervised classifi- cation of patterns into groups of similar objects. It is square variance of the grayscale values of the neighbor pixels are also cal- culated as an additional judge condition, so that the result of the proposed algorithm is the edge of the im- age.

- Facts - This is the most simple segmentation method which is based on a clip level to turn grey scale image in to a binary image.

an iterative process which is terminated when all clusters contain perceptually similar data.

- Facts - This method divides the image into k clusters. The algorithm returns output in the cluster by calculating mean value from

the center of the clusters and then segmenting the images through these clusters. [16]

- Major Drawbacks -

1. Hard partitioning of the data i.e. each point is attributed to only one cluster.
2. Noise could be interpreted as new segments spatial information makes it less general.
3. This technique is guaranteed to converge, but there is a possibility that it may not return the optimal solution.
4. The initial set of clusters taken and value of Kdecides the overall quality of the solution.

5. FCM- FCM algorithm implies the image level of each data pixel according to a membership function in multiple clusters. It enhances the overall attribute of highlighted image according to fuzzy based clusters.

- Facts - Fuzzy c-means has been a very important tool for image processing in clustering objects in an image. FCM can be applied with the spatial term to improve the accuracy of clustering under noise.
- Major Drawback-It takes slight more computational time for image segmentation.

IV. COMPARISON

Comparison table is drafted having a scale of High, Medium, low for specific type of algorithm which is based upon the outcome of results.

In this paper a comparative analysis between different types of segmentation algorithms has been performed.

Parameters for comparison – sensitivity for noise, robustness, Sharpness, smooth partitioning, speed & accuracy.

Table 1 – comparison of segmentation algorithms

Parameter	**Edge detection**	**Threshold**	**Region Growing**	**K-means**	**Fuzzy c means**
Smoothness	Low	Low	Low	Medium	High
Noise Sensitivity	High	High	Medium	Low	Low
Sharpness	Low	Low	Medium	High	High
Robustness	Low	Low	Low	Medium	High
Accuracy	Low	Low	Medium	Medium	High
Speed	Medium	Medium	Medium	High	High

V. SELECTION OF TECHNIQUE

Comparative analysis of various algorithms has been carried out in this paper using several images of different image size.

Various image quality matrices and other image segmentation parameters are studied and depending upon the experimental results the performance of listed algorithms is evaluated. The major parameters which are taken in accordance are Sensitivity to Noise, Smoothness, Sharpness, Robustness, Accuracy and Speed.

Fuzzy C Means algorithm which is in general termed as FCM this is a kind of iterative algorithm which is derived from the fuzzy clustering logic. Each and ev- ery image data element in various classes is classified in a membership degree. The objective of FCM is to minimize J, the objective function J which can be ex- pressed as follows:-

$$J(X, Y, U) = \sum_{j=1}^{K} \cdot \sum_{i=1}^{N} U_{ij}^{m} \, d^{2}(X_i, Y_j) \qquad (1)$$

Where -

X = (Xi, i=1…...N)

K: Number of clusters;

N: Total number of image pixels

Yj: Center of i^{th} cluster

$d^2(Xi,Yj)$: Distance between the pixel Xi and Yj

Uij^m: Degree of membership

and m: the fuzzy degree.

The spatial matrix U satisfies the conditions as de- tailed in following equations -

$$0 \leq U_{ij} \leq 1, \forall\, i \in \{1, \dots, N\} \text{ and } \forall j \in \{1, \dots, K\} \quad (2)$$

$$\sum_{j=1}^{k} U_{ij} = 1 \;\; \forall\, i \in \{1, \dots N\} \quad (3)$$

$$U_{ij} = \left[\sum_{l=1}^{K} \left(\frac{d^2(X_i, Y_j)}{d^2(X_i, Y_l)}\right)^{\frac{1}{m-1}}\right]^{-1} \quad \forall i \in \{1, \dots, N\} \quad (4)$$

$$Y_j = \frac{\sum_{i=1}^{K} U_{ij}^m X_i}{\sum_{i=1}^{K} U_{ij}^m}, \forall j \in \{1, \dots, K\} \quad (5)$$

FCM Algorithm

Step 1:

Initialize the parameters: X = (Xi, i =l ….. N)

K: Number of clusters m: Fuzzy degree

ε: Threshold value which represents the convergence error

Step 2:

Initiate and process the matrix U for initialization us- ing different random values of degree membership in the given interval [0, 1] where it also satisfies the condition in (3).

Step 3:

Repetition-Update the matrix with centers of the cluster Y in (5).

Update the degree of membership for matrix U in (4)

For getting the stability of the matrix (Y) -

$$(Y^{new} - Y^{old}) < \varepsilon$$

It has been observed that ‘m’ parameter, introduced by Bezdek, refers to the fuzziness degree of the parti- tion. As per Bezdek, the value of ‘m’ must be greater than 1 since the choice of m plays an influential role in processing of FCM algorithm. [13]

During the research, use of open source technology or even licensed software has been emphasized. FCM i.e. Fuzzy C-Means algorithm is a way of clustering which allows participation of an image in more than single clusters. [18]

The image pixels which are finite in number are at- tempted for partition in to a group of fuzzy clusters i.e. “c” with respect to a defined criterion.

Various types of similarity measures might be used for identification of classes which are based upon the data and the application. Connectivity, intensity and distance are few examples of values that can be used as different similarity measures.

The center of the clusters can be derived by effectively using FCM algorithm. In this paper, we have tried to accomplish a better understanding on various segmentation algorithms and their parameters which affects their performance.

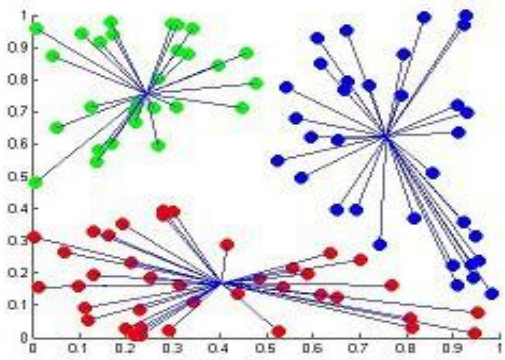

Figure 1 – Fuzzy c means clustering

As represented in Fig. 1, image multiple image pixels are grouped in different clusters which are designated by red, blue and green color. The convergence point of group of theses image pixels are pointing to the cluster center.

Fuzzy c-means algorithm is based on minimization of the objective function. Therefore the FCM algorithm yields the clustered image based on the number of clusters used like in figure1. The main object in fore- ground portion of the input image is grouped into one particular cluster which can be easily extracted.

VI. CONCLUSION AND FUTURE WORK

In this paper, we derived and shortlisted a novel segmentation approach, which is based on fuzzy c- means clustering for obtaining optimal performance efficiency while image segmentation.

Clustering using fuzzy C-means (FCM) algorithm proved to be superior over the other clustering approaches in terms of segmentation efficiency. But the major drawback of the FCM algorithm is the huge computational time required for convergence.

Since FCM require more computational time, it should not be considered that it is slow. It is much fast and speedy than the other segmentation algorithms.

This makes Fuzzy C-Means an ideal algorithm to start our research and find an outcome for increasing the time efficiency in case of image processing and segmentation by use of Parallel Techniques.

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