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An Enhanced Algorithm for Color Image Segmentation

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Abstract* — The image segmentation forms the basis for processing and analyzing an image required for most of the applications. For the segmentation of the color images, a novel approach is proposed in this paper by integrating the advantages of the mean shift (MS) segmentation and the normalized cut (Ncut) partitioning methods. This approach results in effective and robust segmentation of color images and requires low computational complexity and is therefore proved utilitarian for real-time image segmentation processing. The proposed approach is having two phases, preprocessing and post postprocessing. In preprocessing, segmented regions are formed by applying the MS algorithm maintaining the desirable discontinuity characteristics of the image. The graph structure is used to represent the segmented regions and then the Ncut method is applied to perform globally optimized clustering. As conventional graph partitioning methods are directly applied to the image pixels, hence possesses more complexity but in this approach, the complexity is significantly reduces because the number of the segmented regions is much smaller than that of the image pixels, therefore allows a low-dimensional image clustering. Operating on regions instead image pixels, also reduces the sensitivity to noise and results in enhanced image segmentation performance. The robustness and effectiveness of the proposed method is tested and verified through a large number of experiments using color images.

***Keywords* — Segmentation, Normalized cut, Mean shift Clustering**

I. INTRODUCTION

Segmentation is the very first step in almost all the image processing application where the properties of objects in image need to be analyzed e.g. in medical imaging problems in automotive vision in vehicle detection; object recognition in content based image retrieval etc. The objective of the image segmentation is to extract the dominant colors. The image segmentation is very important to simplify an information extraction from images, such as color, texture, shape, and structure. The applications of image segmentation are diversely in many fields such as image compression, image retrieval, object detection, image enhancement, and medical image processing. Several approaches have been already introduced for image segmentation.[1]

A formal definition of image segmentation is as follows: If P( ) is a homogeneity predicate defined on groups of connected pixels, then segmentation is a partition of the set F into connected subsets or regions ($S_1, S_2, ...S_n$) such that $\bigcup_{i=1}^{n} S_i = F$ with $S_i \cap S_j = \emptyset \quad (i \neq j)$.The uniformity predicate P(S_i)= true for all regions, S_i and P ($S_i \cup S_j$) = false, when $i \neq j$ and S_i and S_j are neighbors.[2]

In computer vision, segmentation refers to the process of partitioning a digital image into multiple segments (sets of pixels, also known as super pixels) such that each segment is homogeneous and the union of no two adjacent segments is homogeneous. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region is similar with respect to some characteristic or computed property, such as color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristics. Image segmentation is a key step in many applications in pattern recognition, computer vision and image understanding to allow further image content exploitation in an efficient way. According to several authors, segmentation terminates when the observer's goal is satisfied but still there needs to develop a unique method for it. There are many algorithms and methods are available for segmentation.

The classification of existing algorithms for image segmentation can be categorized as i.e., feature-space-based segmentation, spatial segmentation, and graph-based segmentation. In feature-space-based clustering approaches, [3], [4] the global characteristics of the image captured through the selection and the image features are calculated, normally based on the color or texture. With the use of a particular distance measuring technique not considering the spatial information, the feature samples are handled as vectors, and the effort is to group them into compact, but well-separated clusters.

The feature-space-based clustering approaches have some severe shortcomings. There is no provision for preservation of the spatial structure and the detailed edge information of an image and if feature spaces of pixels overlap, then pixels from disconnected regions of the image may be clustered in one group. In order to keep the edge information intact alongwith the spatial relationship between the pixels on the image plane, the images are to be handled in spatial domain [5]. The watershed algorithm [6] is an extensively used technique for this purpose. A very large number of small but quasi-homogenous regions are produced. Hence, some merging algorithm need to be applied to these regions [5]-[7].

Graph-based approaches are based on the fusion of the feature and spatial information and referred as image perceptual grouping and organization methods In such approaches, several key factors such as similarity, proximity, and continuation are decisive to visual group. Generally, in these approaches, there is the formation of a weighted graph, where each vertex corresponds to n image pixel or a region, and the weight of each edge connecting two pixels or two regions represents the likelihood that they belong to the same segment. The color and texture features, as well as the spatial characteristic of the corresponding pixels or regions decide the weights. There is a partitioning of the graph into multiple components for the minimization of some cost function of the vertices. Until now, several graph cut-based methods have been developed for image segmentations [8], [9]. For example, Wang and Siskind [9] developed an image-partitioning approach by using a complicated graph reduction.

Shi and Malik [9] proposed a general image segmentation approach based on normalized cut (Ncut) by solving an eigen system. The normalized cut criterion measures both the total dissimilarity between the different groups as well as the total similarity within the groups. The Ncut method can robustly generate balanced clusters and shown that it outperformed the other spectral graph partitioning methods, such as average cut and average association [9]. However, Ncut based image segmentation approach in general, requires high computation complexity and, therefore, cannot be applied for real-time processing [9]. An efficient remedy to this concern is to derive the regions by some region segmentation method and then employ the graph representation strategy on these regions. In [7], the authors have developed an image segmentation method that integrates region based segmentation and graph-partitioning scheme. Firstly, a set of oversegmented regions from an image is produced by using the watershed algorithm, and then a graph structure is then applied to represent the relationship between these regions. The watershed algorithm used in [5] and [7] effects in the inherent oversegmentation produces a large number of small but quasi-homogenous regions, which is the cause of a loss in the salient features of the overall image and, therefore, results in deterioration of performance in the consequent region grouping.

To solve these problems, the a novel approach is proposed in this correspondence that provides effective and robust image segmentation with low computational complexity by incorporating the mean shift (MS) and the Ncut methods. In the above stated method, initially image region segmentation is performed by using the MS algorithm [10], and then treated these regions as nodes in the image plane and apply a graph structure to represent them. The final step is to apply the Ncut method to partition these regions.[1]

II. MEAN SHIFT CLUSTERING AND NORMALIZED CUT ALGORITHM

A. Mean Shift clustering

Mean shift clustering is non-parametric clustering technique which does not require prior knowledge of the clusters. Mean shift algorithm clusters an n-dimensional data set. For each point mean shift computes its associated peak by first defining a spherical window at the data point of radius r and computing the mean of points that lie within the window. Algorithm then shifts the window to the mean and repeats until convergence. At each iteration the window will shift to a more densely populated portion of data set until peak is reached where data is equally distributed.

The procedure of situating maximum value of density function among the given isolated data sampled from that function. This is an iterative method, starting with an initial estimate *d*. Let $K\,(d_i - d)$ be a given Kernel function. This function determines the weight of nearby points for re-calculation of the mean. Typically Gaussian kernel is, used on the distance to the current estimate, $K\,(d_i - d) = e^{c\|d_i - d\|}$. The weighted mean of the density in the window determined by *K*

$$m(d) = \frac{\sum_{d_i \in N(d)} K\,(d_i - d)\, d_i}{\sum_{d_i \in N(d)} K\,(d_i - d)}$$

where *N* (*d*) is the neighborhood of *x*, a set of points for which *K (d) ≠0* The mean-shift algorithm now sets, $d_n \leftarrow m\,(d)$ and repeats the estimation until *m(d)* converges.

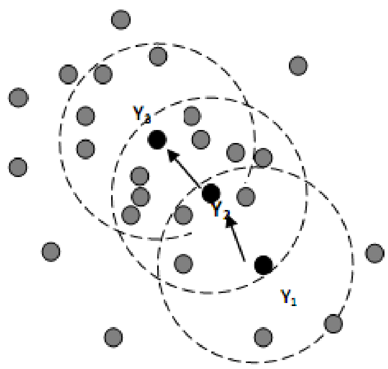

Fig.2.1 Mean shift procedure

An example illustrating mean shift procedure is shown in Fig.3.4 The shaded and black dots denote the data points of an image and successive window centers respectively. Mean shift procedure starts at Point Y_1, by defining spherical window of radius r around it, algorithm then calculates the mean of data points that lie within the window and shifts the window to the mean and iterates the same procedure until peak is reached. At each iteration window is shifted to the more densely populated region.[10]

B. Normalized Cut Algorithm
Normalized cut is a global criterion for partitioning the graph used for segmentation of image. Normalized cut criterion measures both the total dissimilarity and similarity between different groups. A graph *G = (V, E)* can be partitioned into two disjoint sets, *A*, *B*, $A \cup B$, $=V$, $A \cap B = \emptyset$ by simply removing edges connecting the two parts. The degree of dissimilarity been removed. In graphical language, it is called the cut.

$$cut\ (A, B) = \sum_{\mu \epsilon A, \vartheta \epsilon B}^{n} W(\mu, \vartheta)$$

The successful bi-partitioning of a graph is the done when it minimizes this cut value. Although there are a various number of such partitions, in the past lot of work was done for finding the minimum cut of a graph. Wu and Leahy [11] proposed a clustering method based on this minimum cut criterion. They partition a graph into k-sub graphs such that the maximum cut across the subgroups is minimized. By finding the minimum cut this problem can be efficiently solved by them. However the minimum cut criteria favors cutting small sets of individual nodes in the graph. Fig. 3.3 illustrates one such case

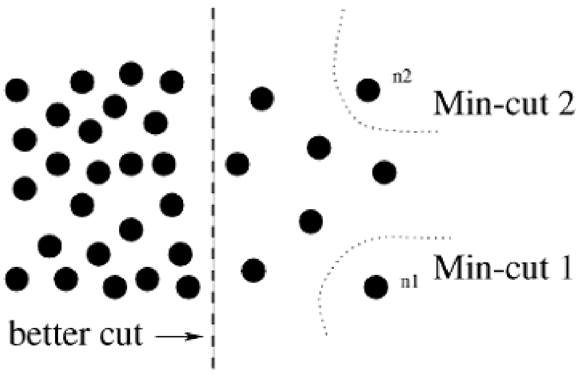

Fig. 2.2 An Example Illustrating that Minimum Cut gives a Bad Partition.

From figure 2.2 any cut those partitions out individual nodes on the right half will definitely have smaller cut value than the cut that partitions the nodes into the left and right halves. To avoid this problem of partitioning small sets of points, [8] propose a new measure of finding cut between two groups. Instead of looking at the value of total edge weight connecting the two partitions, they computes the cut cost as a fraction of the total edge connections to all the nodes in the graph and call this disassociation measure the normalized cut (Ncut).[8]

$$N\ cut\ (A, B) = \frac{cut\,(A, B)}{assoc\,(A, V)} + \frac{cut\,(A, B)}{assoc\,(B, V)}$$

Where $assoc(A, V) = \sum_{\mu \epsilon A, t \epsilon V}^{n} W(\mu, t)$ is a total connection from nodes A to all nodes in the graph and *assoc(B,V)* is similarly defined. However if there are more pixels in the image, more graph of nodes will be generated and this will cause difficulties to solve this algorithm.[9]

III. PROPOSED APPROACH

When we apply graph partitioning techniques directly on images, it has appeared to be inefficient and more complex with low operating speed . If Ncut is directly applied on image pixels, more graph nodes will be generated and this will cause difficulties to perform the segmentation. To overcome the limitations of Normalized cut (Ncut) algorithm by using the merits of mean shift algorithm, integration of both Mean shift and Normalized cut algorithms is done in the proposed approach.

The proposed method consists of following steps

1. An image is preprocessed into multiple separated regions by using mean shift algorithm so each region will be extracted.

2. One region node will be used instead of one region. These region nodes give information about feature vector and spatial location. These region nodes are represented as a weighted unidirected graph which is input to the Ncut algorithm and the dissimilarity measure btween the regions is defined and the weight matrix W is computed.
3. The Ncut method for region nodes clustering is applied to obtain a properly segmented image is obtained.

Fig. 3.1 Block Diagram of Proposed Work

IV. DESCRIPTION OF ALGORITHMS

Procedure for implementing the algorithms is as follows:

A. Mean shift algorithm

The natural scene image is considered as an input image and the given procedure is to be followed:

Step 1: First the variables required for mean shift procedure are taken which includes threshold for this algorithm.

Step 2: Then during mean shift clustering on the image data, it first select the random seed point to start this algorithm, this point is used as a start of this algorithm and start of mean. Location of this point is initialized as a mean.

Step 3: Then the loop until convergence is executed and the the distance from mean which we have chosen in step2 to all points are squared for the given image, then by calculating points within the bandwidth a vote it is mark that this point is belongs to this particular cluster. The mean we have calculated is saved as a old mean and new mean is calculated, again the points within the bandwidth is added to this cluster and these points are mark that they are visited.

Step 4: After executing the above loop if the condition of threshold is satisfied the cluster is stopped.

Step 5: Merge possibilities of the new cluster and old cluster is check and if the distance from possible new cluster maximum to old cluster maximum is within the half of bandwidth the new and old clusters are merged.

Step 6: By executing the above 5 steps a point which belongs to the cluster with maximum votes is treated as a member of the newly formed cluster. A final result is generated which is clustered image it provides the information like member of cluster cell, mean of the cluster and number of clusters. [11]

B. Normalized cut Algorithm

The Normalized cut Algorithm is executed according to the following steps.

Step 1: Before applying the Ncut the data is preprocessed which is output from mean shift to find insignificant cluster to make it background and generate the input data for Normalized cut (Ncut).

Step 2: After this weight matrix is generated, weight between any two nodes is the Euclidean distance between the intensity vectors of pixel corresponding to the nodes, the Ncut is applied on this pixels or region nodes.

Step 3: Ncut calculates the eigen vector and eigen values for the given datapoints then it evaluates the possible region structures from scene image to provide the color image segmentation. [12]

V. EXPERIMENTAL RESULTS

We have applied the proposed algorithm for the segmentation of a set of color images with natural scenes. In this section, we present the experimental results, indicating the different stages of the method. The sizes of all the test images are kept flexible. We considered the computational cost of the proposed method. A PC, which is equipped with a 2.0-GHz Dual Core CPU and 1GB memory and MATLAB 7.10 as an image processing tool is used.

For measuring the performance of color image segmentation based on Mean Shift Clustering and Normalized Cut method, it is applied on various images and output of this algorithm at various stages is determined. The result of this method is illustrated in table. the resultant images are as shown below.

Image 1

(a) (b) (c) (d) (e)

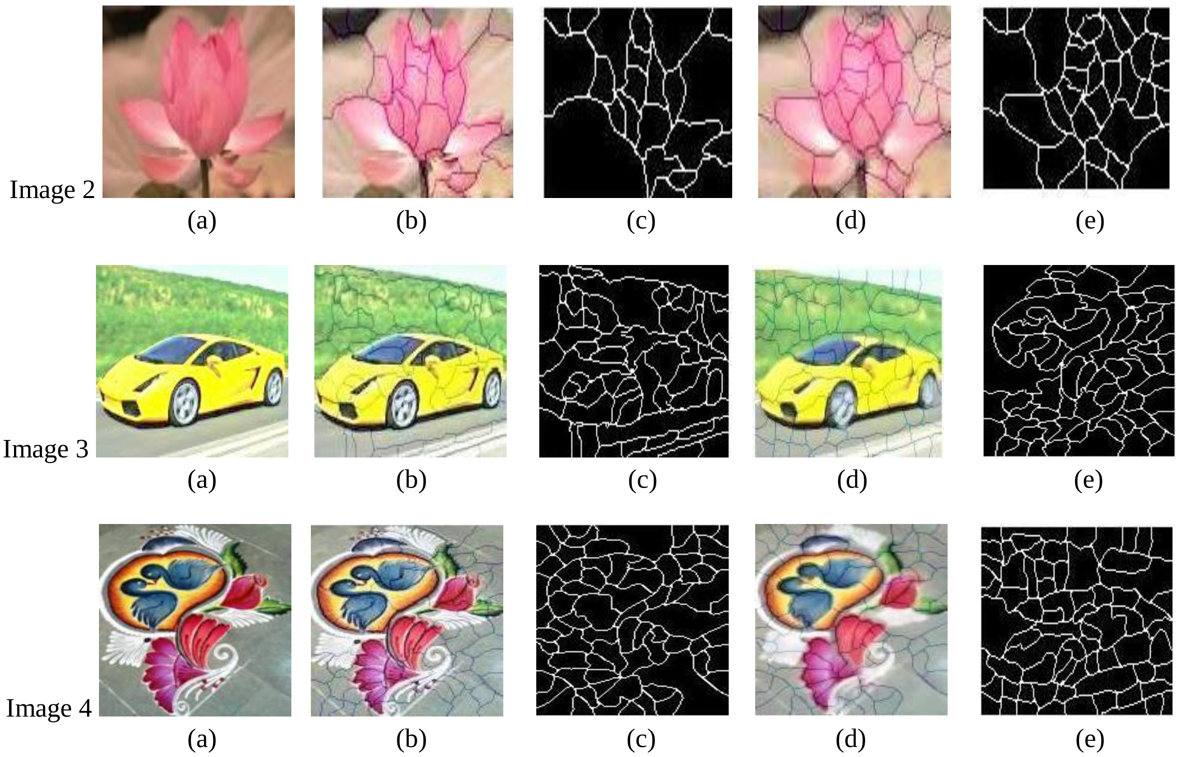

Fig 5.1 Experimental Results for Image 1 (a) Input Image (b) Resultant Image after Applying NcutAlgorithm (c) Edges of regions (d)Result of Meanshift+Ncut Algorithm (e) Edges of regions

Table 5.1 Calculated Time at Each Stage in segmentation

Input	**Number of Cluster**	**Ncut time (s)**	**Mean Shift + Ncut time (s)**
Image 1	38	22.48	20.57
Image 2	25	6.91	6.49
Image 3	53	22.37	20.80
Image4	64	28.77	26.68

VI. CONCLUSION

In this correspondence, a new algorithm is developed for the segmentation of color images. The proposed algorithm takes the advantages of the MS segmentation method and the Ncut grouping method, whereas their drawbacks are avoided. The use of the MS method permits the formation of segments that preserve discontinuity characteristic of an image. On the other hand, the application of the region adjacent graph and Ncut methods to the resulting segments, rather than directly to the image pixels, yields superior image segmentation performance. The proposed method requires significantly lower computational complexity and, therefore, is feasible to real-time image processing.

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