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Overview of Colour Image Segmentation Techniques

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Abstract— Image segmentation is very essential step in image processing and pattern recognition. The segmentation an important research field and several segmentation methods have been proposed in the literature. In image processing and computer vision, segmentation plays an important role as the first step before applying to images higher-level operations such as recognition, semantic interpretation and representation. This paper provides review of main color image segmentation methods and cooperative segmentation method. The segmentation process can be improved by integrating the edge and region information to take the advantage of the complementary nature of such information. Multiresolution strategy in post-processing integration used for boundary refinement gives accurate results.

Keywords— Color image segmentation, edge-based segmentation, region-based Segmentation, cooperative segmentation method

I. Introduction

Image Segmentation is first essential step in low level vision. It is partitioning of the image into a set of disjoint regions which are visually distinct and uniform with respect to some property, such as grey level, texture or color. The problem of segmentation has been, and still is, an important research field and many segmentation methods have been proposed in the literature [1], [2], [11]. A formal definition of image segmentation is as follows: [1], [3]

Definition : 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 (S1, S2, · · · , Sn) such that

$$\bigcup_{i=1}^{n} Si = F \text{ with } S_i \cap S_j = \phi \text{ when } i \neq j$$

The uniformity predicate $P(S_i)$ is true for all regions S_i and $P(S_i \cup Sj)$ is false when Si is adjacent to Sj .

Segmentation plays an important role in object recognition, scene understanding and image understanding. There are several applications of segmentation such as in a vision guided car assembly system the robot needs to pick the appropriate components from the bin for which segmentation followed by recognition is required. Its application varies from detection of cancerous cells to the identification of an airport from remote sensing data. In these applications, quality of final output largely depends on the quality of segmented output [1]. A brief introduction to color image segmentation is given in [1], and also mentions that color images can be considered as a special case of multi-spectral images and any segmentation method for multi-spectral images can be applied to color images. Segmentation methods are categorized based on two basic properties of the pixels with respect to their local neighbourhood: discontinuity and similarity. Boundary-based methods or edge-based methods are based on discontinuity property of the pixels, whereas region-based methods are based on similarity property.

Segmentation can be related to image classification problem based on color and spatial features. Therefore, segmentation methods can be classified as supervised or unsupervised learning classification procedures. Comparison of different color spaces like RGB, normalized RGB, HIS, hybrid color space and brief view on supervised learning algorithms for segmenting fruit images are discussed in [6]. Supervised algorithms include Maximum Likelihood, Decision Tree, K Nearest Neighbour, Neural Networks, etc. Six unsupervised color image segmentation approaches such as adaptive thresholding, fuzzy C-means, SCT /center split, PCT (principal components transform), median cut, split and merge, multiresolution segmentation are explored in [7]. The detailed description of various unsupervised and supervised approaches to color image segmentation can be found in [8,9,10].

The paper focuses on two major groups of segmentation techniques: edge-based, region-based schemes and cooperative segmentation scheme. The rest of the paper is organized as follows. In Sect. II, we give a description on the edge based methods, region based methods and cooperative segmentation methods. Conclusion is given in Sect. III.

II. Color Image Segmentation Techniques

In addition to intensity, color provides additional information. Color is essential for pattern recognition and computer vision. Also the acquisition and processing hardware for color images have become more available and accessible to deal with the computational complexity caused by the high-dimensional color space. Hence, color image processing has become increasingly more practical. One of the major problem of color segmentation is how to employ color information as a whole for each pixel. When color is projected onto three components, color information is so scattered that color images become simply multispectral images and the kind of information that humans can perceive is partially lost. As a

consequence, a particular segmentation method can be directly applied to each component of the color space separately or on the contrary to work with color as a whole representation. For the first case, problem arises when trying to combine the partial results in some way to obtain the final segmentation, whereas for the latter case, the difficulty is that of finding a useful color space and metric to compare color differences. The choice for an appropriate color space is entirely an image/application-dependent question. There is not any color space which is better than others and more suitable to all kinds of images yet, since each color representation has its advantages and disadvantages.
A review of available color image segmentation techniques is provided in [2]. However, color segmentation approaches are based on monochrome segmentation approaches operating in different color spaces. The properties of several color representations, the segmentation methods and color spaces (RGB normalized RGB space HIS, CIE Luv, YIQ, YUV and their properties) are discussed in [4] and segmentation approaches are categorized into four classes namely, pixel based segmentation, area based segmentation, edge based segmentation and physics based segmentation.The complexities encountered in segmenting color images with complex texture is analysed in [5]. Only two color spaces, RGB and HSI are discussed Texture is considered to be the major problem for all segmentation techniques, so much more focus is on texture analysis than on color representation and the problems of feature extraction in images with textural variations are discussed particularly.

A. Edge Based Segmentation
Segmentation can be achieved by detecting edges among the regions. Segmentation techniques based on discontinuity find abrupt changes in the intensity value. These methods are called as Edge or Boundary based methods. An edge is a set of linked pixels lying on the boundary between different regions, where there are deep discontinuities such as gray change, color distinctness, texture variety and so on [13]. Edge detection is mostly utilized for gray level image segmentation, which is based on the detection of discontinuity in gray level, trying to find points with abrupt changes in gray level. Edge detection techniques are usually classified into two categories sequential and parallel [1], [2].
1) Parallel edge detection: A parallel edge detection technique involves the decision of whether or not a set of points are on an edge is independent of whether other sets of points lie on that edge or not. Therefore, the edge detection operator can be applied simultaneously all over the image. One of the technique is high emphasis spatial frequency filtering. As high spatial frequencies are associated with sharp changes in intensity, one can enhance or extract edges by performing high- pass filtering using the Fourier operator. There are various types of parallel differential operators such as Roberts, Sobel, and Prewitt operators which are called the first difference operators and the Laplacian operator, which is called the second difference operator. The main differences between these operators are the weights assigned to each element of the mask. These operators cannot detect ill-defined edges that are formed by a gradual change in gray level across the edge. The disadvantage is, since the computation is based on a small window, the result is quite susceptible to noise.
2) Sequential edge detection: In this technique the result at a point is dependent on the result of the previously examined points. There are a number of sequential techniques which utilize heuristic search and dynamic programming. The performance of a sequential edge detection algorithm will depend on the choice of a good initial point, and it is not easy to define a termination criterion.
In a monochrome image, edge is a discontinuity in the gray level and can be detected only when there is a difference of the brightness between two regions. However, in color images, the information about edge is much richer than that in monochrome case. Accordingly, in a color image, an edge should be defined by a discontinuity in a three-dimensional color space, Reference [14] gives three alternatives for the definition of a color edge. i) Define a metric distance in some color space and use discontinuities in the distance to determine edges. Hence the result cannot be expected to be better than that achieved by edge detection in an equivalent monochrome image.
ii) Consider a color image as composed of three monochrome images formed by the three color components respectively and apply gray level edge detection on these three images separately. Then the edges detected in the three images can be merged by some specified procedures. This is still essentially a gray-level edge detection technique and may be unsatisfactory in some cases [15], [16].
iii) Impose some uniformity constraints on the edges in the three color components to utilize all the components simultaneously, but allow the edges in the three color components to be largely independent.
Two main edge-based segmentation methods are discussed in [23]: Gray-histogram technique in which quality of edge detection depends greatly on the selection of threshold T and Gradient-based method in which Gradient is the first derivative for image f(x,y) . When the change of gray value near edge is large enough and there is little image noise, Gradient-based method works well, and segmentation result is adaptive to the direction of gradient. Three most commonly used Gradient-based methods are differential coefficient technique, Laplacian of Gaussian (LoG), and Canny technique. Among them Canny technique is the most effective.
Thus the conclusion derived is edge detection cannot segment an image by itself. It can only provide useful information about the region boundaries for the higher level systems, or it can be combined with other techniques , e.g. region based techniques [17], [18], [19], [20], [21], [22] to achieve good segmentation results. Edge based methods have problem with images that are edgeless, very noisy, containing smooth boundary or texture boundary.

B. *Region Based Segmentation*
Region-based segmentation schemes aim to group pixels with similar characteristics into regions. Region based approaches includes region growing, region splitting, split and merge. Among region-based methods, region growing is often used in semi-interactive segmentation software. This technique is popular for its simple, flexible and intuitive use.

1) *Region Growing*: Region Growing [24] is one of the simplest and most popular algorithms for region based segmentation. The implementation starts by choosing a starting point called seed pixel. Then, the region expands by adding similar neighbouring pixels according to a certain homogeneity criterion, increasing step by step, the size of the region. So, the homogeneity criterion has the function of deciding whether a pixel belongs to the growing region or not. The decision of merging is basically taken based only on the contrast between the evaluated pixel and the region. However, it is not easy to decide when this difference is small (or large) enough to take a decision. The edge map provides an additional criterion on that, such as the condition of contour pixel when deciding to aggregate it. When contour is encountered it signifies that the process of growing has reached the boundary of the region, so the pixel must not be aggregated and the growth of the region has finished.

One problem with region growing is its inherent dependence on the selection of seed region and the order in which pixels and regions are examined [25].

2) *Region Splitting*: In the region splitting approach, the initial seed region is simply the whole image. If the seed region is not homogeneous, it is usually divided into four squared quadrants (subregions) which become new seed regions. This process is repeated until all subregions are homogeneous. The disadvantage of region splitting is that the resulting image closely resembles the data structure used to represent the image and comes out to be too square.The region merging approach is often combined with region growing or region splitting to merge the similar regions for making a homogeneous region as large as possible.

Region splitting methods are less sensitive to noise than the region growing methods. In both approaches, their iterative structure leads to computationally intensive algorithms.

3) *Split and Merge Technique*: Two basic steps of split and merge technique [26] are as follows. First, the whole image is considered as one region. If this region does not satisfy a homogeneity criterion the region is split into four quadrants (subregions) and each quadrant is tested in the same way; this process is recursively repeated until every square region created in this way contains homogeneous pixels. After that in the second step, all adjacent regions with similar attributes may be merged following other (or the same) criteria. The criterion of homogeneity is generally depending on the analysis of the chromatic characteristics of the region. A region with little standard deviation in the color of its pixels is considered homogeneous. The integration of edge information allows adding to this criterion another term to take into account. So, a region is considered homogeneous when is totally free of contours [25].

These techniques work best on images with an obvious homogeneity criterion and are less sensitive to noise because homogeneity is typically determined statistically. They are better than feature space thresholding or clustering techniques by considering both feature space and the spatial relation between pixels simultaneously. However, problem is all region based approaches are by nature sequential and another problem with these techniques is their inherent dependence on the selection of seed region and the order in which pixels and regions are examined.

Region splitting approach to segment color images are used in [27], [28], [29], [30]. The homogeneous criteria utilized by them are based on 1D histogram thresholding on the features of color components or features extracted from color spaces. A color segmentation approach which combines region growing and region merging techniques is proposed in [31]. It starts with the region growing process using the criteria based on both color similarity and spatial proximity. Euclidean distance over R,G,B color space is used to define the color similarity which defines three criteria of color homogeneity the local homogeneity criterion (LHC) corresponding to a local comparison between adjacent pixels, the first average homogeneity criterion (AHC1) corresponding to a local and regional comparison between a pixel and its neighborhood, considering only the region under study and the second average homogeneity criterion (AHC2) corresponding to a global and regional comparison between a pixel and the studied region. The regions generated by region growing process are then merged on the basis of a global homogeneity criterion based on color similarity to generate a non-partitioned segmentation consisting of spatially disconnected but similar regions. The problem with this method is that the selection of the thresholds for these criteria is rather subjective and the thresholds are image dependent. Another problem is that it is not applicable to images with shadows or shading. In order to recognize the small object or local variance of color image.

[32] proposed a hierarchical segmentation which identifies the uniform region via a thresholding operation on a homogeneity histogram.

The region-based approach is widely used in color image segmentation because it considers the color information and spatial details at the same time [2].

C. Cooperative Segmentation Methods

Unfortunately, both boundary-based and region-based, often fail to produce accurate segmentation. It is not possible to obtain satisfactory results when using any one of these methods in the segmentation of complex pictures such as outdoor and natural images, which involve additional difficulties due to effects such as shading, highlights, non-uniform illumination or texture. Therefore, to improve the segmentation process, the edge and region information can be combined to take the advantage of the complementary nature of such information [25]. One of the main characteristics of these approaches is the timing of integration: embedded in the region detection or after both processes [33].

1) *Embedded Integration*: In this strategy the edge information, previously extracted, is usually used within a region segmentation algorithm. For example, edge information can be used to define the seed point from which the regions are grown. Hence, in region based algorithm resulting segmentation will inevitably depend on the particular growth chosen [34], as well as the choice of the initial region growth points [35]. Many of the common problems of region based method can be avoided by this integration strategy.

The embedded methods can be differentiated between those using boundary information for seed placement purposes, and those which use this information to establish an appropriate decision criterion.
Control of decision criterion: edge information is included in the definition of the decision criterion which controls the growth of the region.
Guidance of seed placement: edge information is used as a guide in order to decide which is the most suitable position to place the seed (or seeds) of the region-growing process.
As discussed previously, one of the disadvantages of the region growing and merging processes is their inherently sequential nature. Hence, the final segmentation results depend on the order in which regions are grown or merged. The edge based segmentation allows for deciding this order, in some cases simulating the order by which humans separate segments from each other in an image (from large to small) [36], or in other proposals giving the same opportunities of growing to all the regions [37].
2) Post-processing Integration: In this strategy, post-processing integration is performed after processing the image using the two different approaches (boundary-based and region-based techniques). That is edge and region information are extracted independently in a preliminary step. A posterior process fuses the dual information in order to modify, or refine, the initial segmentation obtained by a single technique. The aim of this strategy is the improvement of the initial results and the production of a more accurate segmentation. The post-processing methods can be differentiated in three different approaches: over-segmentation, boundary refinement, and selection evaluation.

Over-segmentation: This approach makes use of a segmentation method with parameters specifically fixed to obtain an over-segmented result. Then additional information gained from other segmentation techniques is used to eliminate false boundaries which do not correspond with regions. Pavlidis and Liow [19] has discussed, the major reason which explains why region growing produces so much false boundaries is that the definition of region uniformity is too strict, as when they insist on approximately constant brightness while in reality brightness may vary linearly within a region. It is very difficult to find uniformity criteria which exactly match these requirements and not generate false boundaries.
Boundary Refinement: A region-based segmentation yields a good detection of true regions, although as is well known that the resultant sensitivity to noise causes the boundary of the extracted region to be highly irregular. Hence, in this approach, the region segmentation results are considered as a first approximation to segmentation, with well defined regions, but inaccurate boundaries. Typically, a region-growing procedure is used to obtain an initial estimate of a target region, Information from edge detection is combined to refine region boundaries and to obtain a more accurate representation of the target boundary.

Examples of this strategy are the works of Haddon and Boyce [38], Chu and Aggarwal [39] or the most recent of Sato et al. [40]. There are two basic techniques to refine the boundary of the regions are:
- Multiresolution: this technique is deals with the analysis of image at different scales. A coarse initial segmentation is refined by increasing the resolution. The multiresolution approach is used to carry out the refinement. The image is analysed at different scales, using a pyramid or quadtree structure. The algorithm consists of an upward and a downward path; the former has the effect of smoothing or increasing the resolution in class space, at the expense of a reduction in spatial resolution, while the latter attempts to regain the lost spatial resolution, preserving the newly won class resolution. Spann and Wilson [41] has used a quadtree method using classification at the top level of the tree, followed by boundary refinement. A non-parametric clustering algorithm is used to perform classification at the top level, yielding an initial boundary, followed by downward boundary estimation to refine the result. The Multiresolution strategy provides the best performance with respect to the simplicity of the algorithm and the accuracy of the results.
-Boundary refinement by snakes: In this, the region information is combined with dynamic contours, concretely snakes. The refinement of the region boundary is done by the energy minimization of the snake.
Selection-Evaluation: in this approach, edge information is used to evaluate the quality of different region-based segmentation results, with the aim of choosing the best. This techniques deals with the difficulty of establishing adequate stopping criteria and thresholds in region segmentation.

III. Conclusion

In this paper, an overview of color image segmentation techniques has been presented. We can conclude that there does not exist a universal algorithm for segmenting all types of images. Also most of the techniques are tailored for particular application and work under certain hypotheses. Edge detection methods cannot segment an image by itself and can only provide useful information about the region boundaries. It can be combined with other techniques such as region based techniques. The region-based technique is often used in color image segmentation because it considers the color information and spatial details at the same time. However, problem is all region based approaches are by nature sequential and their inherent dependence on the selection of seed region and the order in which pixels and regions are examined. Hence, the final segmentation results depend on the order in which regions are grown or merged.
However, both edge-based and region-based, often fail to produce accurate segmentation when using any one of these methods in the segmentation of complex pictures such as outdoor and natural images. Therefore, to improve the segmentation process, the edge and region information can be combined to take the advantage of the complementary nature of such information. In general post-processing algorithms give better results than the embedded one. In post-processing, the multiresolution strategy provides the best performance according to the simplicity of the algorithm and the accuracy of the results.

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