Color Image Segmentation Based on SRG And Wateshed Algorithm

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Abstract:

In this paper, we present an automatic seeded region growing algorithm for color image segmentation. The method uses regions rather than pixels as the seeds of SRG. The architecture of the algorithm can be described as follows. First, the input RGB color image is transformed into YCbCr color space. Second, we use watershed segmentation to initialize the image. Third, the initial region seeds are automatically selected according to two rules advanced by us. Fourth, the color image is segmented into regions. Finally, region-merging method is used to merge similar or small regions. Compared with pixel-based SRG algorithm, our method will give more robust and precise results.

Keywords:

Image segmentation; Color image processing; Seeded region growing; Region-merging

I Introduction

Image segmentation is an essential but critical component in low level vision, image analysis, pattern recognition, and now in robotic systems. Besides, it is one of the most difficult and challenging tasks in image processing, and determines the quality of the final results of the image analysis. Intuitively, image segmentation is the process of dividing an image into different regions such that each region is homogeneous while not the union of any two adjacent regions. An additional requirement would be that these regions had a correspondence to real homogeneous regions belonging to objects in the scene.

The classical broadly accepted formal definition of image segmentation is as follows .If P(o) is a homogeneity predicate defined on groups of connected pixels, then the segmentation is a partition of the set I into connected components or regions $\{C_1, \ldots, C_n\}$ such that

$$\bigcup_{i=1}^{n} C_i \text{ with } C_i \cap C_j = \Phi, \text{ all } i \neq j$$

The uniformity predicate $P(C_i)$ is true for all regions C_i and $P(C_i \cup C_j)$ is false when $i \neq j$ and sets C_i and C_j are neighbors. Additionally, it is important to remember here that the image segmentation problem is basically one of psychophysical perception, and therefore not susceptible to a purely analytical solution, according to. Maybe that is why, literally, there are hundreds of segmentation techniques in literature. Selection of an appropriate segmentation technique depends on the type of images and applications [1].

There are primarily four types of segmentation techniques: thresholding, boundary-based, region-based, and hybrid techniques. Thresholding is based on the assumption that clusters in the histogram correspond to either background or objects of interest that can be extracted by separating these histogram clusters[2-3].Boundary-based methods assume that the pixel properties, such as intensity, color, and texture, should change abruptly between different regions [4-5]. Region-based methods assume that neighboring pixels within the same region should have similar values (e.g. intensity, color, texture)[6-7,9]. Hybrid methods tend to combine boundary detection and region growing together to achieve better segmentation [11].

Seeded region growing (SRG) is one of the hybrid methods proposed by Adams and Bischof [12]. It starts with assigned seeds, and grow regions by merging a pixel into its nearest neighboring seed region. Mehnert and Jackway [13] pointed out that SRG has two inherent pixel order dependencies that cause different resulting segments. The first-order dependency occurs whenever several pixels have the same difference measure to their neighboring regions. The second-order dependency occurs when one pixel has the same difference measure to several regions. They used parallel processing and re-examination to eliminate the order dependencies. Fan et al. [14] presented an automatic color image segmentation algorithm by integrating color edge extraction and seeded region growing on the YUV color space. Edges in Y, U, and V are detected by an isotropic edge detector, and the three components are combined to obtain edges. The cancroids between adjacent edge regions are taken as the initial seeds. The disadvantage is that their seeds are over-generated.

In this paper, we apply the SRG to color images with automatic seed selection. We also develop strategies to avoid the two order dependencies. The rest of this paper is organized as follows. In Section 2, we give an overview of our algorithm. In Section 3, we present the method for watershed image segmentation. In Section 4, we present the method for automatic seed selection. Section 5&6 describes the region growing & merging process respectively. Conclusions are made in Section 7.

II. Overview of the Algorithm

In this paper, we combine the SRG based regions and watershed method together for color image segmentation. Instead of using pixels as the initial seeds, we use regions, which are obtained via watershed segment processing, as the initial seeds.

Figure 1 has shown the outline of our algorithm. In first step, the color image is transformed from RGB to YC_bC_r color space. In second step, we apply watershed Image Segmentation algorithm to initialize segmentation. In third step, automatic seed selection to obtain initial seeds. In fourth step, the seeded region growing algorithm is used to segment the image into regions, where each region corresponds to one seed. In last step, the region-merging algorithm is applied to merge similar regions, and small regions are merged into their nearest neighboring regions.

A color image is specified in RGB components. The RGB model is suitable for color display, but is not good for color analysis because of its high correlation among R, G, and B components. Besides, the distance in RGB color space does not represent the perceptual difference in a uniform scale. In image processing and analysis, we often transform these components into other color spaces. Chenget al. [15] compared several color spaces including RGB,YIQ, YUV, normalized RGB, HIS, CIE L*a*b*, and CIE L*u*v* for color image segmentation purposes. Every color space has its advantages and disadvantages. Garcia and Tziritas [16] noticed that the intensity value Y has little influence on the distribution in the C_bC_r plane and the sample skin colors form a small and very compact cluster in the C_bC_r plane. The YC_bC_r color space has been extensively used for skin color segmentation [15-18]. In this paper, we use the YC_bC_r color space for segmentation due to three reasons: (1) YC_bC_r color space is widely used in video compression standards (e.g. MPEG and JPEG) [17]; (2) the color difference of human perception can be directly expressed by Euclidean distance in the color space; (3) the intensity and chromatic components can be easily and independently controlled.

The YC_bC_r color space is a scaled and offset version of YUV color space, where Y, U, and V represent luminance, color, and saturation, respectively. The C_b (C_r, respectively) is the difference between the blue (red, respectively) component and a reference value [18]. The transformation from RGB to YC_bC_r can be performed using Eq. (1), where R, G, and B are in the range of [0, 1], Y is [16, 235], and C_b and C_r are [16, 240].

$$\begin{bmatrix} Y \\ C_b \\ C_r \end{bmatrix} = \begin{bmatrix} 65.481 & 128.553 & 24.966 \\ -39.797 & -74.203 & 112 \\ 112 & -93.786 & -18.214 \end{bmatrix} \times \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} \qquad (1)$$

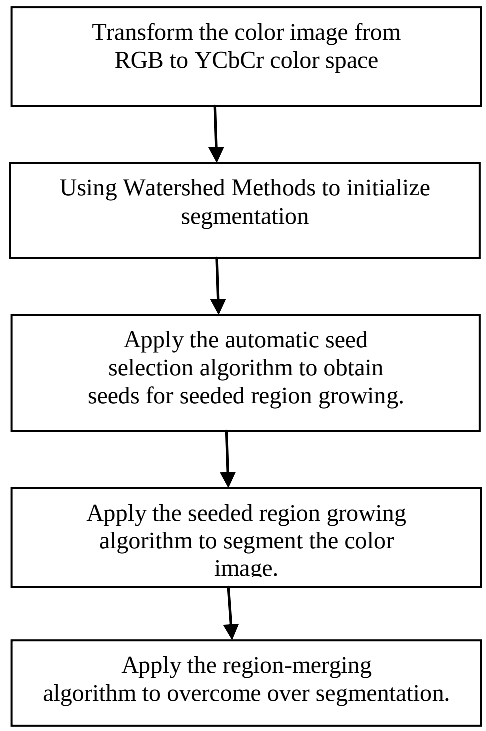

Figure 1 Outline of the proposed algorithm.

III. Watershed Image Segmentation Method

The watershed algorithm is more representative in the application of mathematical morphology theory for image segmentation. Watershed algorithm is a region-based segmentation techniques image that uses image morphology [19]. Watershed algorithm is an iterative adaptive threshold algorithm. The idea of watershed algorithm is from geography (shown in Figure 2), it see gradient magnitude image as a topographic map, the gradient magnitude in correspond with altitude, the different gradient in correspond with the peak and basin in valley in the image. It sees every object of image (including background) as a separate part and requested there must have one tag at least in the each object (or seed points). Marker is knowledge about the object based on application-oriented; it is selected by the operator manually or by automatic process. The objects can use watershed algorithm to transform and develop regional growth after maker.

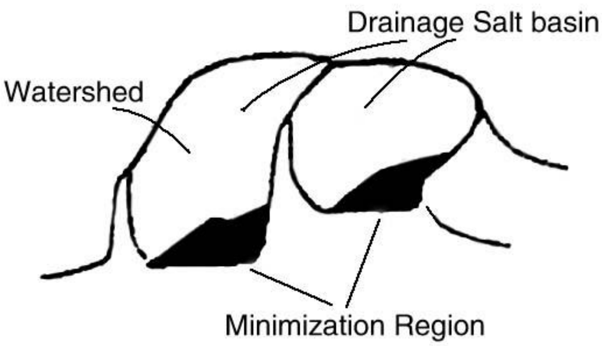

Figure 2 The Schematic diagram of watershed algorithm

Watershed algorithm acts as one of the most powerful tool for image segmentation.

Fortunately, the regions of the over-segmentation can be qualified as the initial seeds for SRG. Compared with pixels, the regions obtained via watershed algorithm have more information.

IV. The method for automatic seed selection

For automatic seed selection, the following three criteria must be satisfied. First, the seed pixel must have high similarity to its neighbors. Second, for an expected region, at least one seed must be generated in order to produce this region. Third, seeds for different regions must be disconnected.

We calculate the similarity of a pixel to its neighbors as follows. Considering 3x3 neighborhood, the standard deviations of Y, C_b, and C_r components are calculated by using

$$\sigma_x = \sqrt{\frac{1}{9}\sum_{i=1}^{9}(x_i - \bar{x})^2}, \quad (2)$$

where x_i can be Y, Cb, or Cr, and the mean value $\bar{x} = \frac{1}{9}\sum_{i=1}^{9} x_i$. The total standard deviation is

$$\sigma = \sigma Y + \sigma C_b + \sigma C_r \quad (3)$$

We normalize the standard deviation to [0, 1] by

$$\sigma_N = \sigma / \sigma_{max} \quad (4)$$

Where σ_{max} is the maximum of the standard deviation in the image. The similarity of a pixel to its neighbors is defined as

$$H = 1 - \sigma_N \quad (5)$$

From the similarity, we define the first condition for the seed pixel candidate as follows:

Condition 1 A seed pixel candidate must have the similarity higher than a threshold value.

On the side, we calculate the relative Euclidean distances (in terms of YCbCr) of a pixel to its eight neighbors as

$$d_i = \frac{\sqrt{(Y - Y_i)^2 + (C_b - C_{b_i})^2 + (C_r - C_{r_i})^2}}{\sqrt{Y^2 + C_b^2 + C_r^2}} \quad (6)$$

i=1, 2…8.

From our experiment, the performance of using relative Euclidean distance is better than using normal Euclidean distance. For each pixel, we calculate the maximum distance to its neighbors as

$$d_{max} = \max_{i=1}^{8}(d_i). \quad (7)$$

From the maximum distance, we define the second condition for the seed pixel candidate as:

Condition 2 A seed pixel candidate must have the maximum relative Euclidean distance to its eight neighbors less than a threshold value.

A pixel is classified as a seed pixel if it satisfies the above two conditions. In order to choose the threshold value automatically for Condition 1, we use Otsu's method. The threshold is determined by choosing the value that maximizes the discrimination criterion σ^2_B / σ^2_W, where σ^2_B is the between-class variance and σ^2_W is the within-class variance. For Condition 2, we select the value 0.05 as the threshold based on our experiments.

Each connected component of seed pixels is taken as one seed. Therefore, the seeds generated can be one pixel or one region with several pixels. Condition 1 check whether the seed pixel has high similarity to its neighbors. Condition 2 makes sure that the seed pixel is not on the boundary of two regions. It is possible that for one desired region, several seeds are detected to split it into several regions. The over segmented regions can be merged later in the region merging step.

V. Region Growing process

In this section, we introduce region growing process. Suppose that there are totally N regions after watershed process. Before region growing, we need to construct a N*(N+2) matrix BB, where each row memorizes the neighbor regions of a region, together with the total number of its neighbors and a label denoting which seed region it will be merged. We show our region growing algorithm as follows:

(1) Perform automatic seed region selection process described in section 4.

(2) Label each seed region with its own sequence number.

(3) While there are regions unlabeled in BB, loop throughout every seed region row, and loop throughout their neighbor regions table. Take out this seed region's neighbor denoted by p which is not a seed region. check p's all neighboring regions. If all labeled neighbors of p have the

same label, set p to this label. After p is labeled; p will be deleted from the seed region's neighbor regions table. Accordingly the number of this seed region's neighbor regions will be subtracted by 1. We denote the seed region that merges the region p by q. After p is merged, first, update the total number of pixels, Then update region q's neighboring region by adding all of region p's unlabeled neighboring regions. Last, update region number of all region q's neighboring regions.

(4) Perform region-merging discussed in section 6.

Note that in step (3), when all regions in BB are labeled, in other words, when each region is classified into some seed region, the loop is over.

VI. Region-merging process

It is possible that several seeds are generated to split a region into several small ones. To overcome the over segmentation problem, we apply region-merging. Two criteria are used: one is the similarity and the other is the size. If the mean color difference between two neighboring regions is less than a threshold value, we merge the two regions. Unfortunately, the result of region-merging depends on the order in which regions are examined. In our method, we first examine the two regions having the smallest distance value among others. In each iteration, if this value is less than a threshold, we merge the two regions and re-compute the mean of the new region and the distances between the new region and its neighboring regions. We repeat the process until no region has the distance less than the threshold. The color difference between two adjacent regions Ri and Rj is defined as the relative Euclidean distance

$$d(R_i,R_j)=\frac{\sqrt{(\bar{Y}_i-\bar{Y}_j)^2+(\bar{C}_{b_i}-\bar{C}_{b_j})^2+(\bar{C}_{r_i}-\bar{C}_{r_j})^2}}{\min(\sqrt{\bar{Y}_i^2+\bar{C}_{b_i}^2+\bar{C}_{r_i}^2},\ \sqrt{\bar{Y}_j^2+\bar{C}_{b_j}^2+\bar{C}_{r_j}^2})}. \quad (8)$$

Based on our experiments, we select 0.1 as the threshold for color similarity measurement. Next, we check the size of regions. If the number of pixels in a region is smaller than a threshold, the region is merged into its neighboring region with the smallest color difference. This procedure is repeated until no region has size less than the threshold. Since variations of image complexity could be large, some has a high number of regions and some has small sized regions. In order to achieve better segmentation results, we further perform merging by controlling the size of regions and the color difference between regions. In the region merging, we set the relative Euclidean difference threshold 0.1 for initial merging. If this threshold is too high, some desired region may be merged with other regions; oppositely, there will be too many regions. We set the size of region threshold as 1/150 of the image size. By using too high threshold, some important objects may be merged to other regions, while too low threshold may lead to over segmentation.

VII Conclusion

The application of image processing has widely applied in our life, in which the digital image processing technology is widely used in all aspects of life. Image segmentation is a key step for transition to the image analysis as low-level processing in digital image processing. For a long time, all kinds of image segmentation methods are dedicated to the study of the gray image, with the improvement of computer processing capabilities and the increased application of color image, the color image segmentation are more and more concerned by the researchers Color image segmentation methods can be seen as an extension of the gray image segmentation method in the color images, but many of the original gray image segmentation methods cannot be directly applied to color images. This requires to improve the method of original gray image segmentation method according to the color image have the feature of rich information or research a new image segmentation methods which specially used in color image segmentation, and thus it is a goal of researcher to make it have the advantage of universal property and good treatment effect. In this paper, we have presented a novel segmentation algorithm for color images with automatic seed selection. Unlike traditional SRG algorithm, where the seeds are always pixels, our method use regions as initial seeds, so selected initial seeds can provide more accurate segmentation of images. Using region as seeds, our algorithm can also enjoy much improvement in efficiency.

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