

Color Image Segmentation Based on Parameter-Dependent Connected Components

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Abstract

A theory of a parameter-dependent connected components of gray images that takes into account both the gray values of the pixels and the differences of the gray values of the neighboring pixels has been introduced in a previous work. The concept of the parameter-dependent connected components has been applied to gray-scaled images for segmentation successfully. In this paper, the author investigates a method to apply the concept of the parameter-dependent connected components to color images for segmentation.

1. Introduction

Image segmentation is defined in Pavlidis [1] as a partition of an image into connected subsets, each of which is a maximal uniform set. According to Haralick and Shapiro [2], the subsets need to be uniform and homogeneous with respect to some characteristic (such as gray level, color or texture) and adjacent subsets should be significantly different with respect to the chosen characteristic. Ideally, each such subset would represent a meaningful object in the image. The importance of image segmentation lies in that it constitutes the first abstraction of scene level information from the raw intensity values of the pixels. Many futher image processing, such as object recognition and scene interpretation, are heavily rely on the quality of the segmentation process. A number of research has been devoted to the development of segmentation techniques applicable to a wide class of color images. These techniques can be divided into three major categories: edge detection [3, 4], region growing [5, 6, 7], and thresholding or clustering [8, 9, 10]. The first two categories of the techniques operate in local areas and usually miss global activity, while the techniques in the third category operate in a global area and often miss the local activity. In this paper, the author introduced a new method for segmentation of color images, which makes use of both local and global information of an image. A great deal of existing research in image segmentation deals with monochrome images. Compared to a monochrome image, a color image provides, in addition to intensity, additional information on the objects in the image. Usually, grey level techniques cannot be used in a straightforward way because of the vectorial nature of color images.

Recently, the concept of (ϵ, δ)-components of gray-scale images that takes into account both the gray values of the pixels and the differences of the gray values of the neighboring pixels, where ϵ, δ are two parameters was introduced [11]. Each (ϵ, δ)-component may contains the pixels which have different gray values. We have discussed [11] some properties of (ϵ, δ)-components which may help us to analyze and understand the structure of an image in a higher level. In [11], we described an algorithm to find the (ϵ, δ)-components for a given image and the values of the parameters. The experimental results gave in [12, 13] have show that for some appropriate parameter values, an (ϵ, δ)-component may represent an object of an image reasonably well. So, the properties of the (ϵ, δ)-components describes the properties of the corresponding objects of the image. Thus, we may understand the content of an image through the properties of its (ϵ, δ)-components. Segmentation with (ϵ, δ)-components is simiar to a method of region growing. It relies on the local information of a pixel. On the other hand, selection of the values of the parameters ϵ and δ takes into account the globle information of the images. Therefore, this method utilies both local and global information of an image. In this paper, we shall discuss how to apply the concept of (ϵ, δ)-components of gray-scale images to color images, and how to perform segmentation on color images.

2. Preliminaries

To make this paper self-contained, we review briefly some definitions from our previous work [11].

A gray image Σ is represented by a set of points each of which has a certain *gray value* representing the intensity of brightness of the point. We shall use $\sigma(p)$ to denote the gray value of the point p. Although, theoretically, $\sigma(p)$

could be any number, we shall take it, for convenience, to be a non-negative integer. Two points in a gray image Σ are called *adjacent* if they share either a vertex or an edge. Our treatment does not depend on the grid system chosen to represent an image and the way in which the points share vertices or edges. Instead of considering whether the points are 4-, 6- or 8-neighbors (see [14] or [15] for definitions), we shall simply consider here only whether two points are adjacent or not.

A *path* between two points p_0 and p_n in a gray image Σ is a sequence of points $p_0, p_1, \ldots, p_n$ such that $p_i \in \Sigma$ and p_i and p_{i-1} are adjacent for all $1 \le i \le n$. Given non-negative integers ϵ and δ, we say that two distinct points p, $q \in \Sigma$ are (ϵ, δ)-*connected* if there exists a path $p = p_0, p_1, \ldots, p_n = q$, such that the maximal variation of the gray values of the points on the path is less than or equal to ϵ, and the maximal variation of the gray values of any two adjacent points along the path is less than or equal to δ. Such a path will be called an (ϵ, δ)-*connected path* between p and q. A subset of Σ is called an (ϵ, δ)-*connected set* if each pair of points of the subset is (ϵ, δ)-connected. The definition of (ϵ, δ)-connectedness gives us a convenient tool to study the variation of gray values in an image. By varying the parameters ϵ and δ, we may investigate the diverse distribution of gray values. Given a point $p \in \Sigma$, any maximal (ϵ, δ)-connected set containing p is called a *related* (ϵ, δ)-*connected component* (in short, (ϵ, δ)-*RCC*) of p, and is denoted by C_p^Σ; the point p is called the *seed point* of its (ϵ, δ)-RCCs. (By a *maximal* (ϵ, δ)-connected set, we mean an (ϵ, δ)-connected set S such that there exists no other (ϵ, δ)-connected set which contains S properly, *i.e.*, for any point $p' \notin C_p^\Sigma$, there is at least one point $q \in C_p^\Sigma$, such that p', q are not (ϵ, δ)-connected.) For a given image, an (ϵ, δ)-RCC obtained by the algorithm discussed in [11] is called an (ϵ, δ)-component of the given image. The *spectrum* of the gray values of a set of pixels C is defined to be $max_C - min_C$, where min_C, max_C denote the minimum and the maximum of the gray values in C respectively.

3. Segmentation

In order to apply the concept of the (ϵ, δ)-connected components to color images, we split each color image into three primitive images according to its color channels: red, green and blue, respectively. Then, interpret the gray value of the disscusion in the previours section as the intensity of a color primitive on each primitive image accordingly. Base on this interpretation, we can conduct segmentation on each primitive image with the mehtod discussed in [13]. Finally, the three segmented primitive images are combined to generate the final segmented image. Figure 1-(a) shows an original color image. Figure 1-(b) shows the segmented image with $\epsilon = 30$ and $\delta = 5$. The boundary of each combined (ϵ, δ)-connected component is shown as white.

4. Conclusion

A theory of a parameter-dependent connected components of gray images that takes into account both the gray values of the pixels and the differences of the gray values of the neighboring pixels has been introduced in a previous work. The concept of the parameter-dependent connected components has been applied to gray-scaled images for segmentation successfully. In this paper, the author investigates a method to apply the concept of the parameter-dependent connected components to color images for segmentation. The experimental results are preliminary, but promising. Futher experiments will be conducted. The approach can be applied to a wide variety of images as we do not make any assumptions about the image formation model, and the method is independent of the type of grid system used for the digitization process and the type of adjacency relation for the pixels.

5. References

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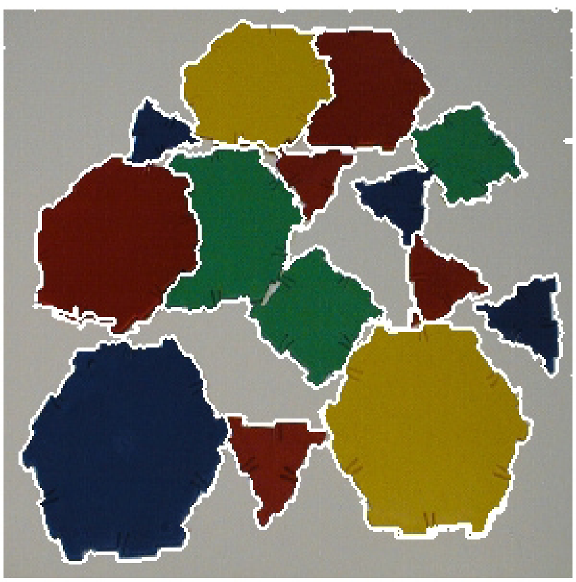
(a)



(b)

Figure 1: *(a) A color image. (b) The segmentation result with* $\epsilon = 30$, $\delta = 5$.

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