Image Clustering Using Graph Cuts in LAB Color Space

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Abstract

In this paper, we developed a novel approach that provides effective and robust segmentation of color images. It preprocesses an image by converting color information from RGB to CIE L*a*b* color spaces that CIE L*a*b* color spaces can express color in a device-independent way. CIE L*a*b* color space is better suited to digital image manipulations than the RGB space, because it had removed correlation among R, G, and B components that in RGB color space. The transfer image is then represented by using the graph structures, and the Ncut method is applied to perform globally optimized clustering and graph cut techniques was used to perform image segmentation tasks. And the experimental results show that the new algorithm performs better.

Keywords: Image segmentation, CIE L*a*b* color spaces, Graph cuts, K-means

1. Introduction

For some applications, such as image recognition or compression, we cannot process the whole image directly for the reason that it is inefficient and unpractical. Therefore, image segmentation plays an essential role as a preliminary step towards further and higher levels of image processing, such as recognition or compression. Image segmentation can identify the regions of interest in a scene or annotate the data. Segmentation accuracy determines the success or failure of computer vision system therefore it is one of the crucial steps that gives the ability to computer vision systems to analyze and detects the objects of interest. The existing segmentation algorithm can be categorized into region-based segmentation, data clustering, and edge-base segmentation. In first approach, an image is partitioned into regions that are similar to a set of predefined criterion. For data clustering, the concept of them is based on the whole image and considers the distance between each data. The characteristic of data clustering is that each pixel of a cluster does not certainly connective. The basis method of data clustering can be divided into hierarchical and partition clustering. In the third approach, the partition of an image is based on abrupt changes in intensity or color such as edges in an image [1].

Color image segmentation has been receiving an increasing attention, because color images convey more information than gray-level images and allow one to obtain more meaningful and robust segmentation. At the same time, color is known to be a strong cue in attracting an observer's attention. Actually, the motivation for using color for segmentation comes from the fact that it provides region information and that when specified appropriately, it can be relatively insensitive to variation in illumination conditions and appearances of objects [2][11].

Fan et al. 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 [3]. Tao et al. incorporated the advantages of the mean shift segmentation and the normalized cut partitioning methods to achieve low computational complexity and real-time color image segmentation [4][16][17].

Most of color image is stored 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. Also, the distance in RGB color space does not represent the perceptual difference in a uniform scale.

In image processing and analysis, Color have different models such as RGB, HSI, L*a*b* and etcetera Color can be transform/convert from one color space to another color system e.g. conversion from RGB to HSI. Cheng et al. 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 [5] [8].
In this paper, we develop a novel approach that provides effective and robust segmentation of color images. The first step of the method is that preprocesses an image by converting color information from RGB to CIE L*a*b* color spaces. The second step, the transfer image is then represented by using the graph structures. Finally, the graph cut techniques was used to perform image segmentation tasks.

2. CIE L*a*b* color model

CIE L*a*b* (CIELAB) is the most complete color space specified by the International Commission on Illumination (French Commission internationale de l'éclairage, hence its CIE initialism). It describes all the colors visible to the human eye and was created to serve as a device-independent model to be used as a reference [6]. A CIE 1931 XY chromaticity diagram has been shown in figure 1.

\[
L = 116f(Y/Y_a) - 16 \quad (1)
\]
\[
a = 500[f(Y/Y_a) - f(Y_a/Y)] \quad (2)
\]
\[
b = 200[f(Y/Y_a) - f(Z/Z_a)] \quad (3)
\]

where \( f(x) \) is \( \sqrt[3]{x} \), if \( x > 0.008856 \), and \( 7.787x + 4/29 \), otherwise. \( X_a, Y_a, Z_a \) are the CIT tri-stimulus values for the illuminant (Judd and Wyszecki, 1975), and \( X, Y, Z \) are derived from the red, green, and blue values.
3. Graph cut techniques and Maximum Cut Problem

In this section we state basic notions on graphs before presenting the definitions of extension and cut over a graph, which will be necessary in the sequel of the paper.

We define a graph as a pair $G = (V, E)$ where $V$ is a finite set and $E$ is composed of unordered pairs of elements of $V$, precisely, $E$ is a subset of $\{\{x, y\} \mid x \neq y\}$. Each element of $V$ is called a node or a vertex (of $G$), and each element of $E$ is called an edge (of $G$). The set of nodes ($V$) consist of two terminal nodes: the source ($s$) and the sink ($t$) and a set of terminal nodes ($P$), that is expressed in Equation 2.

$$V = \{s, t\} \cup P$$ (5)

A simple graph with terminal $s$ and $t$ is shown in Figure 1. From this study, the image segmentation is related to graph theory of grouping which is used to segment image; the graph theory is used to convert the image pixel to a graphical representation. An example of a graph and its minimum cut is shown in Figure 2.

The min-cut optimization problem, defined for a weighted undirected graph $G = (V, E, W)$, consists of finding a bipartition $G$ of the set of vertices or nodes of the graph: $V = (C, C')$, where $V = (C \cup C')$, such that the sum of the weights of edges with endpoints in different subset is minimized. Every bipartition of the set of vertices $V$ into $C$ and $C'$ is usually called a cut or cutset and the sum of the weights of the edges, with a vertex in $C$ and the other vertex in $C'$, is called cut weight or similarity ($s$) between $C$ and $C'$. For the considered min-cut optimization problem, the cut weight or similarity between $C$ and $C'$, given by

$$s(C, C') = \sum_{v \in C, u \in C'} w_{uv}$$ (6)

is minimized, where $w_{uv}$ is the edge weight between nodes $v, u \in V$. From [12] it is demonstrated that the decision version (reformulation of the problem with binary variables) of max-cut (dual version of min-cut problem) is NP-complete. In this way, we need to use approximate algorithms for finding a high-quality solution in a reasonable time. The min-cut approach has been used by Wu and Leahy [14].

\[
\begin{bmatrix}
X \\
Y \\
Z
\end{bmatrix} = \begin{bmatrix}
0.607 & 0.174 & 0.200 \\
0.299 & 0.587 & 0.114 \\
0.000 & 0.066 & 1.116
\end{bmatrix}
\begin{bmatrix}
R \\
G \\
B
\end{bmatrix}
\]

(4)
as a clustering method and applied to image segmentation. These authors search a partition of the image graph into $k$ sub-graphs such that the similarity (min-cut) among sub-graphs is minimized. They pointed out that although for some images the segmentation result is acceptable; in general, this method produces an over-segmentation because small regions are favored. To avoid this fact other functions that try to minimize the effect of this problem are proposed [4]. The function that must be optimized (minimized) called min-max cut is

$$\text{cut}(G) = \frac{\sum_{v \in C, u \in C'} W_{uv}}{\sum_{v \in C, u \in C} W_{uv}} + \frac{\sum_{v \in C', u \in C} W_{uv}}{\sum_{v \in C', u \in C'} W_{uv}}$$

$$= \frac{s(C, C')}{s(C, C)} + \frac{s(C, C')}{s(C', C')}$$

(7)

where the numerators of this expression are the same $s(C, C')$ and the denominators are the sum of the edge weights belonging to $C$ or $C'$, respectively. It is important to remark that in an image segmentation framework, it is necessary to minimize the similarity between $C$ and $C'$ (numerators) and maximize the similarity inside $C$, and inside $C'$ (denominators). In this case, the sum of edges between $C$ and $C'$ is minimized, and simultaneously the sums of weights inside of each subset are maximized. In [24] an alternative cut value called normalized cut is proposed which, in general, gives better results in practical image segmentation problems:

$$\text{Ncut}(G) = \frac{\sum_{v \in C, u \in C'} W_{uv}}{\sum_{v \in C, u \in C} W_{uv}} + \frac{\sum_{v \in C', u \in C} W_{uv}}{\sum_{v \in C', u \in C'} W_{uv}}$$

$$= \frac{s(C, C')}{s(C, V)} + \frac{s(C, C')}{s(C', V)}$$

(8)

Color test image. In figure 3 we show the result of parametric SCC on a color image using 16 labels.

4. Experimental Results

To verify the performance of our method, a set of various images was tested by our methods. To begin the experiment, we download some images from the internet. For all the tested images, the images labeled (a) are original images, these label (b), (c) are using Ncut segmentation algorithm for original images and our method, respectively. For comparisons with existing Ncut method, we use an implementation of Ncut from http://www.csd.uwo.ca/faculty/olga/software.html. A personal computer with 2.20 GHz processor and 2.00GB RAM was used as hardware part of machine vision system and algorithm was developed in MATLAB R2007 version software[18].

The major steps for proposed image cluster segmentation algorithm are summarized as follows:

**Step 1: Read Image**

**Step 2: Convert Image from RGB Color Space to L*a*b* Color Space**

**Step 3: Classify the Colors in 'a*b*' Space Using K-Means Clustering. All examples set the clusters number $C$ to be five ($C=5$).**

**Step 4: Create Images that Segment the H&E Image by Ncut.**

The experimental results are shown in Figures (3, 4, 5and 6).

We have evaluated our method on a set of complex image, which contain foreground objects with higher appearance variations or backgrounds with complex scenes such as fig.1 and fig.5. In fig.5, the Ncuts methods can not distinguish the hand and ring, where two isolated clusters instead of the whole region were segmented; however, our proposed methods can give a good performance.
Figure 3: (a) Source image, (b) Ncut methods segmentation results (c) Proposed approach segmentation results

Figure 4: (a) Source image, (b) Ncut methods segmentation results (c) Proposed approach segmentation results

Figure 5: (a) Source image, (b) Ncut methods segmentation results (c) Proposed approach segmentation results

Figure 6: (a) Source image, (b) Ncut methods segmentation results (c) Proposed approach segmentation results
From above the results of experiments clearly showed that the clustering images of our method are more clearly detailed segmentation results.

4. Conclusion

Most televisions, computer displays, and projectors produce colors by combining red, green, and blue light in varying intensities – the so-called RGB additive primary colors. Lighting condition of greenhouse was not uniform during the image acquisition. The RGB color model could not lonely be used to segment color image, because of high correlation among the R, G, and B components. The CIE L*a*b* color model were successfully able to solve this problem. Because, this color models intensity information of an object is separated from the color information. In this paper, we developed a novel approach that provides effective and robust segmentation of color images. It preprocesses an image by converting color information from RGB to CIE L*a*b* color spaces that CIE L*a*b* color spaces can express color in a device-independent way, based on nonlinearly compressed CIE XYZ color space coordinates. Unlike the RGB, CIE L*a*b* color space is better suited to digital image manipulations, because it had removed correlation among R, G, and B components that in RGB color space. The transfer image is then represented by using the graph structures, and the Ncut method is applied to perform globally optimized clustering and graph cut techniques was used to perform image segmentation tasks. And the experimental results show that the new algorithm performs better. The proposed method is stable and useful for unsupervised image segmentation applications. Extensive experiments have shown that the proposed method is highly robust, flexible and effective.

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