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Feature Discrimination in Large Scale Satellite Image Browsing and Retrieval

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ABSTRACT: Feature discrimination is a critical component in large scale satellite image browsing and retrieval, as well as in other areas of remote sensing. As many satellite images are multi-spectral, the spectral information should be exploited for efficient browsing and retrieval. In this aspect, color is a suitable candidate to represent the spectral contents. This paper presents an efficient algorithm on feature discrimination for browsing and retrieving of large-scale satellite imagery using color features. Our main focus is on color modeling of interest region based on appropriate color space. The description of color features using spherical influence fields allows unrealistic or biased color prototypes to be removed from the color model. And the proposed color model is capable of discriminating the interest region from the image background. Experimental results demonstrated that interest region was successfully discriminated from the complex scene using the proposed color model in the L*a*b color space.

1 INTRODUCTION

Satellite imagery is an indispensable tool for many applications in the field of remote sensing. To manage and analyze this ever-growing volume of data, it is necessary to have an efficient browsing and retrieval system. The feature discrimination helps to answer some user queries, such as, search for a particular landscape with less than 20% cloud cover, or find a vegetation patch that looks like the selected region etc. Several papers [2, 3, 4, 5] have been published in search of efficient descriptors for the feature discrimination in the browsing and retrieving of images. Dubuisson-Jolly and Gupta examined color and texture features independently and fused them using maximum likelihood [5]. Their findings showed that color information provides a better localization of the edges, while texture information provides a less noisy classification of individual regions. In Manjunath's work, texture features were studied and mainly derived from Gabor filters [2, 3, 4]. However, these efforts were designed in particular for ordinary and aerial photos. As many satellite images are multi-spectral, it is necessary to exploit their spectral information for efficient browsing and retrieval. Since color is a suitable candidate in this sense, we are interested to find appropriate color space and model for feature discrimination.

In this paper, we propose the use of L*a*b* color space to process a 3-band satellite image. A prototype-based color model is adopted for color modeling based on Spherical Influence Field. An application to demonstrate the use of this color model on a satellite image is also presented. This paper is organized as follows: Section 2 describes the L*a*b color space for color representation. Section 3 describes the prototype-based color model using Spherical Influence Field. Section 4 shows the experimental results of feature discrimination. Section 5 concludes with discussions and future directions.

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2 COLOR SPACE

The RGB and HSI color spaces are often used in image processing applications. The RGB color space uses additive primaries (Red, Green and Blue) to represent colors. While the HSI color space corresponds more closely to human color perception as it represents color in terms of chromaticity and lightness. In colorimetric terms, chromaticity refers to hue and saturation whereas lightness is related to intensity. In search of a suitable color space [1], we have listed the following criterion,

- **Uniform Characteristics:** equal distance must correspond to approximately equal perceived color difference.
- **Concentrated Distribution:** color distribution are more concentrated in the selected color space.
- **Color Space Conversion:** simple computation for the conversion from RGB to the selected color space.

In a perceptual uniform color space, equal distance between two points in the space corresponds to approximately equal perceived color difference. It is well known, by the Commission Internationale de l' Eclairage (CIE) standards, that RGB color space does not possess the uniform characteristic. On the other hand, the conversion from the RGB to HSI color space is often a complicated task. Hence these two color spaces do not meet our requirements. The L*a*b* color space is formulated by the CIE in 1976. It possesses the uniform characteristic and the computation from RGB via CIE XYZ components to L*a*b* is relatively simple. This color space uses perceived lightness L* and a set of opponent colors, red-green versus yellow-blue as its axes. According to the CIE 1976 standard, the perceived lightness of a standard observer is assumed to follow the physical luminance (proportional to intensity) according to a cubic root law as follows [1]:

1. RGB-XYZ Conversion:

$$X = 0.431R + 0.342G + 0.178B \tag{1}$$

$$Y = 0.222R + 0.707G + 0.071B \tag{2}$$

$$Z = 0.020R + 0.130G + 0.939B \tag{3}$$

2. Cube-root transformation

$$L^* = \begin{cases} 116[Y/Y_n]^{\frac{1}{3}} - 16 & Y/Y_n > 0.008856 \\ 903.3[Y/Y_n] & Y/Y_n \leq 0.008856 \end{cases} \tag{4}$$

$$a^* = 500[f(X/X_n) - f(Y/Y_n)] \tag{5}$$

$$b^* = 200[f(Y/Y_n) - f(Z/Z_n)] \tag{6}$$

Where, X_n, Y_n, Z_n are XYZ tristimulus values of reference white point, $X_n = 95.05, Y_n = 100, Z_n = 108.88$, and

$$f(t) = \begin{cases} t^{\frac{1}{3}} & Y/Y_n > 0.008856 \\ 7.787t + 16/116 & Y/Y_n \leq 0.008856 \end{cases} \tag{7}$$

Furthermore, L*a*b* color space has a concentrated color distribution as compared to its RGB counterpart. To illustrate, both color distributions are plotted for an entire satellite image as shown in Figures 1(b) and 1(c).

3 Color Modeling

A prototype-based approach is adopted in the color modeling. A prototype with spherical influence field is used to collect representative colors of the interest objects. Many color prototypes will be generated from sample learning, they are noise-induced and will be eliminated by the thresholding method.

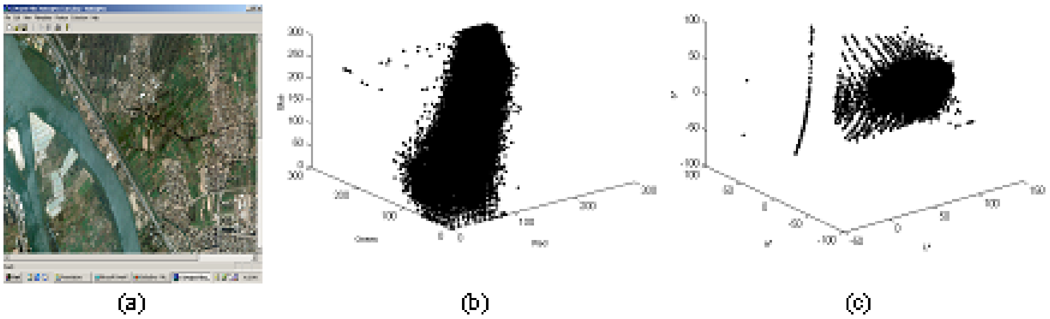


Figure 1. Color Distribution in RGB and L*a*b* Color Space (a)Satellite Image Sample (b)Color Distribution in RGB Color Space (c) Color Distribution in L*a*b* Color Space

3.1 Color Prototype

Let $c_1, c_2, \ldots, c_n$ denote color elements in color set C in the L*a*b* color space. Denote p_i to be a color prototype with a spherical region of radius λ_i and center $\tilde{c}_i$ which covers color set C completely. This spherical region is defined as the "Spherical Influence Field" with its threshold as the radius λ_i (See Figure 2). Define d_i to be the Euclidean distance between the color x and $\tilde{c}_i$ as follows:

$$d_i = |\sum_{j=1}^{3}(c_{ij} - x_j)^2|^{\frac{1}{2}} \tag{8}$$

where c_{ij} and x_j are the L*a*b* coordinate values of center $\tilde{c}_i$ and the color x respectively. Then color x belongs to the spherical influence field of p_i if there is a d_i such that $d_i \leq \lambda_i$.

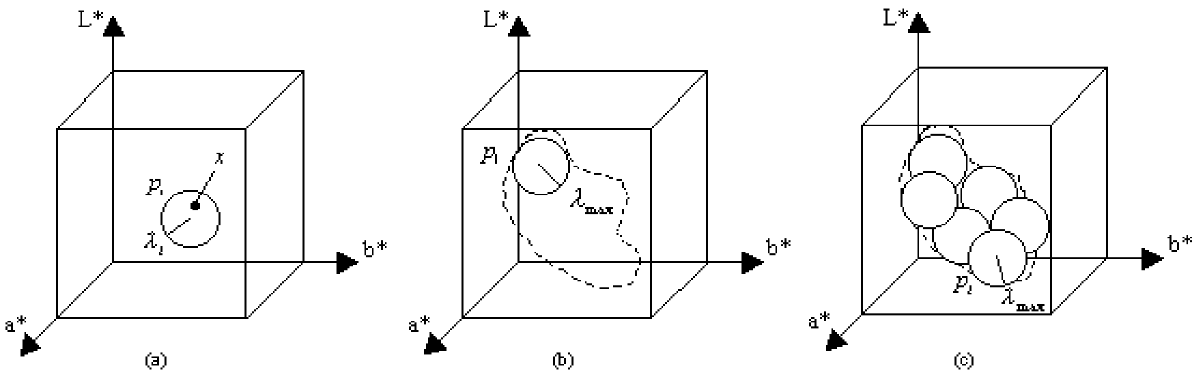


Figure 2. Color Modeling in L*a*b* Color Space (a) Spherical Influence Field of Color Prototype p_i (b) The First Color Prototype in Region Fitting (c) Region Fitting with Multiple Color Prototypes

3.2 Region Fitting

The color prototype collects representative colors of interest object. A combination of prototypes may be used to model the object's color distribution. Define color model M with n color prototypes $p_1, p_2, \ldots, p_n$ generated from color set $C = [c_1, c_2, \ldots, c_n]$ as follows:

1. **First Color Prototype:** The pattern counter k_1 of the first prototype p_1 is set to 1. It is generated based on the first color element c_1 with spherical influence field threshold of λ_1. Subsequent color element is added if it falls into the spherical influence field of p_1. Pattern counter is incremented for every addition of such color element.

2. **Additional Color Prototype:** Suppose one color element c_i falls outside the spherical influence field of any previously created prototypes, a new color prototype will be created, with spherical influence field with the threshold λ_i and the center $\tilde{c}_i$. The pattern counter of the new prototype will be initialized to 1, $k_i = 1$.

3.3 Removal of Noise-induced Color Prototypes

The color prototype is generated from sample colors in the image. If the image is noisy, it will lead to biased color prototypes generated. Consequently, the region fitting will be inaccurate. Hence, we attempt to remove these biased prototypes by the threshold method. Assume that M is a color model that contains m color prototypes $p_1, p_2, \ldots, p_m$, with pattern counters $k_1, k_2, \ldots, k_m$ respectively. The pattern counter indicates the number of color elements in the color prototype. Since noise contains a minority bunch of colors, we can assume that noise-induced color prototypes has relatively low pattern counter. Define w_i as the density weight of color prototype p_i,

$$w_i = \frac{k_i}{\sum_{i=1}^{m} k_i} \tag{9}$$

The density weight for each prototype will be compared against a threshold weight w_T , removing prototypes whose density weight falls below the threshold as follows:

$$\text{if } \; w_i > w_T \qquad w_i \; \text{ is reserved}$$
$$\text{if } \; w_i \leq w_T \qquad w_i \; \text{ is removed}$$

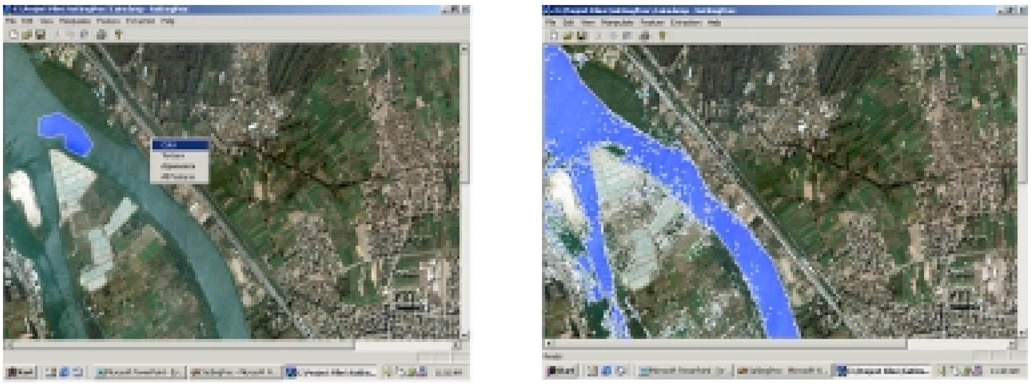
Color distribution of objects may come in different irregular forms. With the proposed color modeling, the combination of prototypes can model the color distribution more accurately.

3.4 Feature Discrimination

Once the region fitting and noise removal for the object of interest is completed, we can perform feature discrimination in the L*a*b* color space. If the pixel falls inside any one of the color prototypes in the color space, it will be labeled as belonging to the interest object, and vice versa.

4 EXPERIMENTAL RESULTS

The proposed color model has been tested for feature discrimination on satellite images. Our object of interest is the river and a sample region has been extracted (enclosed in polygon) to generate color prototypes. Using L*a*b* color space and the proposed color modeling, we aim to discriminate between river and non-river regions. In our experiment, the spherical influence field threshold of each color prototype has been set to 10. The application interface and segmentation results are shown in Figure 3(a) and 3(b) respectively.



(a) (b)

Figure 3. Feature Discrimination in Satellite Image
(a) Selection of River Sample Region (b) Segmentation Results

5 CONCLUSION

In this paper, we have proposed a new color model with L*a*b color space on the application of feature discrimination for satellite images. As color is an important component to the multi-spectral satellite images, it is necessary to exploit the color feature for feature discrimination. With the realization of proposed color model on our application, we can move on to the subsequent stages of large-scale satellite image browsing and retrieval. It is found that the results do not improve a great deal with varying sizes of color prototypes, hence we standardize the size of each color prototype.

Work on texture-based feature discrimination using Gabor filters is in the process. Future work will merge both the color and texture features to improve our software. Thus moving one step forward towards the development of our satellite image browsing and retrieval software.

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