A Fuzzy Clustering Method of Color Image With Semantic Color Tree

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***Abstract*— Fuzzy clustering algorithms have been widely used for image segmentation, typically such as FCM algorithm. However, the FCM algorithm is parameter sensitive, and its results lack of availability. To improve the above problems, a novel fuzzy clustering method based on semantic color tree for image segmentation is proposed in this paper. The method is realized by modifying the membership function in the conventional FCM algorithm and by constructing the semantic color tree to achieve the semantic color extraction, which take human visual subjectivity into account in semantics. The proposed method is applied to real images. Experimental results show that the presented algorithm performs more effectively than the FCM algorithm.**

Keywords-fuzzy clustering; semantic color; semantic tree; color extraction

I. INTRODUCTION

Color image segmentation is an important problem in computer vision and image processing, which has been paid considerable attention by increasing people, with the rapid development of computer processing power. Due to color image providing more information than monochrome image, color images are used in many applications. It aims to partition a color image to several regions which are homogeneous for some measures. From the segmentation result, it is possible for us to obtain regions of interest and specific information in the scene, which is crucial to further analysis and recognition of objects. With regard to color image segmentation, the primary concerned remains the efficiency of segmentation. In recent decades, although the field of color image processing has made great strides, effective and robust image segmentation still don't get well settled because of the particularity and complexity of image itself, and there is not a recognized standard to weight the segmentation quality.

There are many classifications of color image segmentation algorithms, such as supervised algorithms including maximum like-hood method, decision tree method, and neural network, and unsupervised algorithms which segment mainly images in different color spaces. Various image segmentation methodologies based on clustering have been developed for years [1]. Fuzzy clustering-based segmentation is our concern here, which provides an effective method for the intelligent information processing. Meanwhile, an image itself has much uncertainty and inaccuracy, i.e. it is fuzzy. It can’t be well processed with conventional approaches, however, can be resolved by semantic description. Semantic understanding of images remains an important research challenge for computer vision. One's perception of image is often influenced by subjective factors, so it will be more effective to make use of natural description than rigid division.

The segmentation method proposed in this letter utilizes the semantic conception and fuzzy sets [2]. Based on the diversity of color, the relationship of color and semantics can be established, and we defined a mass of color classes in semantics. It turned out to be appropriate to process color image with fuzzy clustering. Given the close relationship between color and semantics [3], we apply semantic color tree to extract color in this paper, and a semantic color database is established, so here puts forward a specific color extraction method based on the semantic color tree. Using existing knowledge and experience to solve the semantic gap between the image semantic and visual features, and with the image color as the representative, we define semantic description vocabularies and membership function, and achieve the semantic division of color image. Color feature of color image, semantic color, the similarity between colors, extraction and retrieval method will be discussed in this paper.

II. MATERIAL AND METHOD

A. Semantic Color

People's perception and understanding of image is based on semantic level. According to the complicacy of semantics, image semantic is generally divided into low-level feature, object semantics and abstract semantics [4]. As one of the low-level features of color image, color also is a important factor which reflects the image semantic information. Color semantic is a low-level feature for image understanding, it is a key that how to description the concept of semantics with a appropriate structure. The relationship between semantic and image can be expressed as the hierarchy model, as showed in Fig. 1. The first layer represents original data of image, the pixels. The physical feature lies on the second layer, which reflects the physical characteristic, such as color, texture, shape and contour. The highest semantic layer conveys our conceptual cognition.

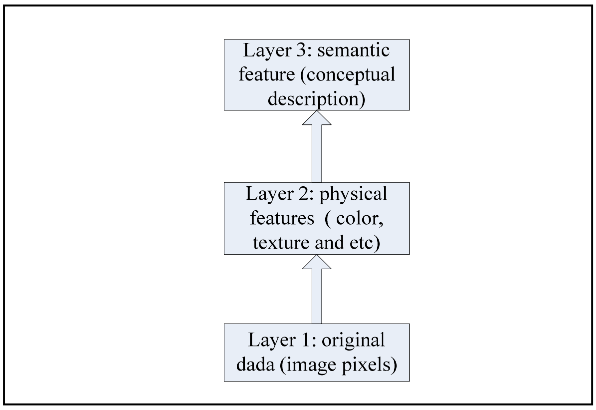


Fig. 1. Semantic layers.

Yu et al. described video scenes and image objects by the means of tree structure, analyzed semantic structure of soccer video with the aid of Hidden Markov Model (HMM) [5]. It is often the case that color is used in video processing system, however, it is more effective in static image processing because of its abundant semantic information. So we analyze semantics by defining various semantic colors.

As for as semantic color, the definitions differ from object to object in application. Several were put forward in video processing. Niu et al. proposed an adaptive color analysis method which realized semantic shot segmentation in video [6]. In image processing, Wang proposed a multi-color extraction method which gave a preliminarily definition of semantic color and built a semantic color model so as to extract specific colors in a color image [3]. However, the proposed method has its limits, and is inadequate. On account of the diversity of reorganization for color, it should be supplied with certain data support like database, which will be supplemented in this paper.

B. Semantic Clor Feature

Feature extraction is required in order to fulfill the feature-based segmentation. Feature extraction tends to find an appropriate measure to characterize the homogeneity of each region in an image. Many features have been investigated in the past, including statistical features, frequency-domain features and model-based features [1]. Feature-based segmentation is a process of assigning each pixel in the observed image a label to designate the region or class which it belongs to. Color is one of important low-level feathers in an image, and the key to reflect semantic information of color image.

After importing the concept of semantic color, we can describe the feature of semantic color. As one of the low-level visual features in image, the semantic feature of color is generally expressed with textual description, which is in line with people's experience. According to semantic description, a large number of semantic color are defined with their features, they can be managed and retrieved by traditional database [7]. At present, the semi-automatic or manual way is used to extract the semantic features, which is not so effective in the large scale database, though. As for provided semantic information, we can locate, recognize and retrieve it in a color image. In the process of feature extraction, the more automated it is, the smaller its scope of application.

The feature of a semantic color can be expressed with a multi-dimensional vector whose elements represent all kinds of property of a color. The basic property is color values. The feature vector can be shown as follows:

$$F = (x_1, x_2 \cdots x_n)$$

Where n is the number of property, and x_i represents the i th property of a color.

It is sensitive for people to recognize colors with eyes. While the color that people perceive is often based on RGB space model where various colors can be composed of the three primary colors to meet human visual effect. However, it has some defects. First and foremost, the RGB space is greatly relevant between the components of a color. The components will vary with the change the brightness of pixel. In addition, the color space is not homogeneous. So the RGB model is not recommended in image segmentation.

A homogeneous color model, L*a*b* is used in this paper, we can transfer RGB into XYZ space with the following formulas:

$$\begin{aligned} X &= 0.620R + 0.178G + 0.204B \\ Y &= 0.299R + 0.587G + 0.144B \\ Z &= 0.056G + 0.942B \end{aligned} \tag{1}$$

The L*a*b* space is widely used in color image segmentation, which is the most complete color model usually used to describe all the colors that are visible by human eyes. The parameters of Lab can be get from above values with the following formulas:

$$\begin{aligned} L^* &= 116 f(Y_1) - 16 \\ a^* &= 500\left(f(X_1) - f(Y_1)\right) \\ b^* &= 200\left(f(Y_1) - f(Z_1)\right) \end{aligned} \tag{2}$$

Where X_1 , Y_1 and Z_1 are obtain through the liner interpolation of the values of X , Y , Z . $f(\cdot)$ is a correction-function.

The color is a kind of important characteristic, interested object can be extracted from image according to color. It is important problem how to extract automatically semantic feature from physical features of a image. Several papers have proposed descriptions about features such as color, texture and sharp. The following sections will discuss similarity between semantic colors.

C. Semantic Similarity Computation

Different colors, the visual people feel is different, which is caused by individually subjective feeling on the concept and description of color. As is often the case, we describe a color with a qualitative word, such as color terms and degree words. So the description is fuzzy, it could be a color range, but not an accurate value. Colors which are seemed similar are actually distinct. In order to extract accurate semantic color, we propose to measure the distance between colors with the max-min formula, which is an effective method of measuring the similarity in fuzzy clustering and is suitable for multidimensional data [8]. In this paper, we will conclude the application of the method with the common semantic colors in the RGB color space.

Distance measure is to obtain the distance between points in the feature space. Murkowski -distance is defined as follow:

$$d(x_i, x_j) = \left(\sum_{k=1}^{m} \left| x_{ik} - x_{jk} \right|^r \right)^{1/r} \qquad (3)$$

Where x_i and x_j are the points in feature space, and $x_i = (x_{i1}, x_{i2}, \dots x_{ik}), k \in (1, m)$ .When $r = 1$, $d(x_i, x_j)$ is known as the Manhattan distance; when $r = 2$, it is the Euclidean distance, which is commonly used.

Extensive use has been made of the max-min distance method in cluster analysis, as shown below:

$$d(x_i, x_j) = \frac{\sum_{k=1}^{m} \left(x_{ik} \wedge x_{jk} \right)}{\sum_{k=1}^{m} \left(x_{ik} \vee x_{jk} \right)} \qquad (4)$$

We have to be based on the specific circumstances to determine which method of distance will be adopted in image segmentation. The max-min distance is used here because of its simplexes and ability to process high dimensional data.

D. Semantic Color Tree

Fuzzy clustering algorithm is used in this paper. Clustering refers to classify samples whose classification is unknown into several classes according to the similarity (membership) among samples. The methods of clustering are numerous and here the max-min distance algorithm is adopted, which is presented above. Meantime, the semantic tree structure is put forward in order to segment or extract semantic colors more intuitively. The semantic structure demonstrates the correlations of semantic colors which will be classified.

The principle of the semantic tree structure can be demonstrated as follow:

The task of image segmentation can be stated as the partition of an image into a number of non-overlapping regions, each with distinct properties. In term of this definition, an image A can be viewed as the union of c homogeneous regions $A_k (k = 1, 2...., c)$:

$$A = \bigcup_{k=1}^{c} A_K$$

where each homogeneous region is specified by the representative properties $V_K(x, y)$, e.g. intensity, and an additive, zero mean random noise component $n_K(x, y)$.

$$A_k(x, y) = v_k(x, y) + n_k(x, y)$$
$$for\ (x, y) \in\ region\ A_k$$

In image processing, $V_K(x, y)$ is the noise component always be removed or filtered with some methods for further research, and the main component of an image is $n_K(x, y)$, which is represented by pixels as the basic units.

A homogeneous region (A_k) should consist of a number of pixels which express some same or similar features such as value, texture, and color. All the features of a pixel can be expressed by an vector, whose data are normalized for the purpose of efficient computation. In this paper, we focus on color of an image as the main property.

Let $X = \{x_i\}, i \in (1, 2, ..., n)$ be the whole set of feature vectors, x_i be the intensity values or the gray values associated with an image defined in the domain.

1) set a threshold λ ,and calculate the similarity u_{ij} between x_i and x_j with the max-min algorithm;

2) Get the membership matrix $U = \{u_{ij}\}$, and a multi-connection graph and connection loops among x_i ;

3) Compare u_{ij} with the value of λ , if $u_{ij} \ge \lambda$, retain the branch between x_i and x_j ,or, cut off, then a simple connected graph can concluded according to the principle of maximal tree.

4) Adjust the value of λ until ideal classification is got.

It can be illustrated by an example. Based on above method, let there are 9 colors to be clustered, and choose C2 as the vertex , a maximal semantic tree is yielded, where 9 colors were denoted by nine points, and they were linked by the branches based on the similarity-relation matrix . The semantic color tree (SCT) can be concluded as shown as the Fig. 2.

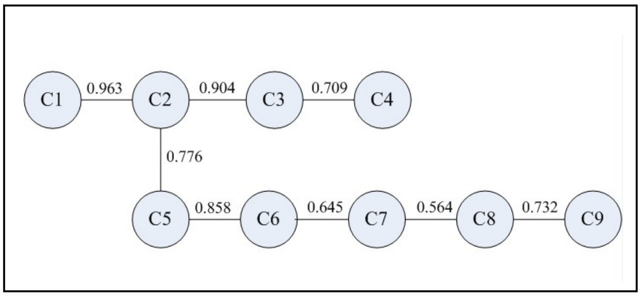


Fig.2. Semantic color tree

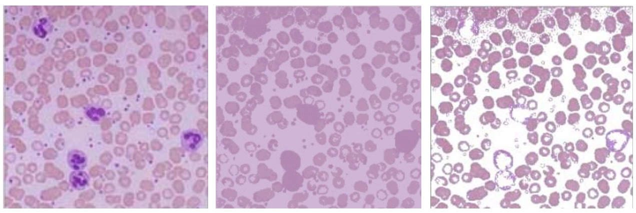
The color features of an image can be divided into several regions with above method. In a color image, the classes of colors are limited and the interesting regions would be focused on in the image processing.

E. Extraction of Semantic colors Based on SCT

In our experiment, the process of color extraction is based on the semantic tree. During the extraction, the Semantic Color Tree (SCT) is seen as a clustering prototype We employ to determine one of target colors to the first center, and then we use fuzzy max-min algorithm to traverse all the pixels of an image since it is the three-dimensional vector of an image which include lots color information. Therefore, we can get memberships of every pixel relative to the center. We set a value of threshold which is compared with the membership, if a membership is bigger than the threshold; we retain the corresponding pixel, or set the pixel to white. And we can estimate the result of extraction, if it is satisfactory, we stop to extract the second color of the object, otherwise the threshold will be reset. So we can extract multiple colors which constitute all color components of the target. Of course the operation of multiple colors is serial. Compared with FCM method [9], we use the max-min algorithm for extracting since color it costs less time without iteration. The result of multi-color extraction of color image will be discussed in the next section.

III. RESULTS AND DISCUSSION

In this section, we investigate the very applicability of the above FMM in color image segmentation. Our experimental results here demonstrate that when the segmentation for color images is required, the above FMM has obvious advantages over FCM.



(a) Original image (b) FCM (c) the proposed

Fig.3. (a-c) Segmentation results of both algorithms

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Fig.4. (a-c) Segmentation results of both algorithms

In the experiment results, Fig. 3 (a) and Fig. 4 (a) show an original color image. Fig. 3 (b) and Fig. 4 (b) show the corresponding segmentation results using FCM, respectively c=2. Fig. 3 (c) and Fig. 4 (c) show the segmentation results using the proposed method. Fig. 3 (d) and Fig. 4 (d) show the results of double colors which compose the object. In the Fig. 3 (b) and Fig. 4 (b), the segmented object is of single feature which has the same RGB value, but the Fig. 3 (c) and Fig. 4 (c) retain the color information and the special distribution of the pixels. By analyzing the segmentation results, we can conclude that Fig. 3(c) has more accuracy color information than Fig. 4(c). Obviously, the segmentation results of the proposed method are better than comparable with those of FCM, from the perceptual viewpoint.

IV. CONCLUTION

In this paper, we put forward a novel color clustering method for color images to accurately extract various color regions. The aim of clustering is to decrease the data volume through generalizing the similar data. Compared with FCM, the proposed method decreases the fuzzy uncertainty in clustering image data. According to the established Semantic Tree Structure, the fuzzy cluster algorithm is easy to distribute the cluster center. The method has been implemented on a set of images, and the results shown its effectiveness .It is suited for color segmentation. And the result of image extraction adds verisimilitude to real image. Furthermore, compared with the FCM algorithm, the proposed method is more flexible, and it improves the processing speed to achieve extraction. However, the result of extraction with the method, to some extent, is affected by the order of color selection, and spatial information is not taken into account, which will be improved in the future.

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