An Improved Watershed Algorithm by using Edge Features and Its Application to the Color Image Retrieval

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Abstract: In this paper, an improved segmentation for color images and its application color retrieval system is elaborated. The method is based on the integrated edge features of H, S, I color space independently using a watershed process that several thresholds, such as markers are set heuristically. In order to solve two major problems of over segmentation and non-segmentation, the integration of regions is utilized by the size of area after the watershed algorithm using the integrated edge features and setting the thresholds of markers in a heuristic sense. To verify the efficiency of this method, the improved watershed algorithm is used to the color image retrieval system.

エッジ特徴を用いた Watershed アルゴリズムの改良とカラー画像検索への応用

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概要：自然画像データを画像内容によって検索する方法として、画像の領域分割による画像オブジェクトの抽出方法がある。この領域分割法として、画像の色空間 H, S, I の各成分から統合エッジを求め、Watershed 法の未分割問題を解決し、さらに、領域統合により、過分割問題を解決した改良 Watershed アルゴリズムを自然画像の領域分割に適用し、良好な自然画像検索結果が得られた。この結果を自然動画像検索による観光案内ガイドへの応用を試みた。

1 Introduction

Color image segmentation techniques have been investigated by many researchers. [1], [2], [3], [4] Watershed algorithms can guarantee a closed and continuous boundaries of segmented areas because the region of contour is obtained by growing it from the basin, called the marker, to the neighboring pixels of boundaries. However, watershed algorithms have two major problems of over segmentation and non-segmentation.

One way to deal with the non-segmentation is the method of extracting the integrated edge of color H, S, I space from images independently. Another way to solve the over segmentation problem is the method of merging the region according to the edge of area after watershed algorithms is applied to the image segmentation.

In order to evaluate this improved watershed algorithm, a color image retrieval system was performed and applied to the tourist information guide effectively.

2 Quantization of Color Space Palette

Most digital color images are presented by the R, G, B color space, but R, G, B values are usually different from human perception. Therefore, we convert the R, G, B values into the H, S, I color space and then the hue value is divided into 12 equal parts.

When the intensity value is extremely small, a color image seems to be almost black. When the saturation value is extremely small and also the intensity value is extremely large, a color image seems to be almost white. When the saturation value is extremely small and the intensity value is medium, a color of images seems to be gray for human perception.

Therefore, the color space C is assumed to be quantized into 15 color space according to Table 1.

Color	Saturation(S)	Intensity (I)
Black		$0.0 \le I \le 0.15$
White	$0.0 \le S \le 0.1$	$0.8 \le I \le 1.0$
Gray	$0.0 \le S \le 0.1$	$0.15 \le I \le 0.8$

Table 1 Quantization of color palette

2 Edge Feature Extractions

Generally, color images have several objects depending on the H, S, I values independently. Therefore, the contour of the objects can be detected by extracting the edge features of H, S, I value independently. For extracting the edge features, we adopt the Prewitt operator which has 8 directions. Each H, S, I components of color images are calculated by this kind of Prewitt operator and then selected the maximum edge value among 8 mask independently. Finally, we can derive the Edge H, Edge S and Edge I respectively using these filters.

Usually, many scenery images have the color characteristics that the significant change of the hue value is observed even though at the region of the smoothness of the intensity values.

Therefore, we can introduce the integrated edge value composed by the Edge H, Edge S, and Edge I with their weighting factors α, β, γ.

Then, we can get the integrated edge value, Edge total, as following equation.

$$Edgetotal = \alpha \bullet EdgeH + \beta \bullet EdgeS + \gamma \bullet EdgeI \qquad (1)$$

Where, $0 \le \alpha, \beta, \gamma \le 1$

3 Improved Watershed Algorithm using the Integrated Edge Features

The watershed transformation constitutes one of the most powerful segmentation tools for images. The watershed algorithm is based on a marker of the different objects that are to be segmented. A marker is constructed, whose different catchment's basins correspond to the desired objects. This binary segmentation process is illustrated in Fig.1.

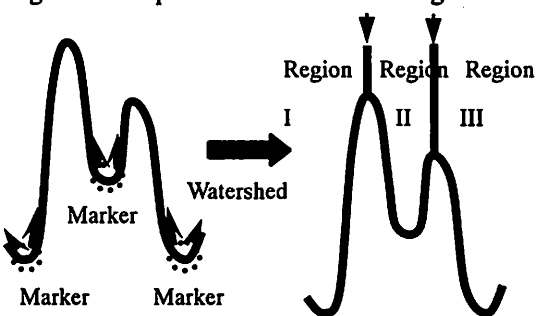


Fig.1 Binary segmentation by watershed algorithm

In order to avoid the major problem of the non-segmentation, we can adopt the minima of the integrated edge value for the marker and then perform the watershed process completely.

When the smaller integrated edge value may be derived, the usual computation of its watershed process mostly results in an over segmentation that many contours are observed. For the elimination of this over segmentation problem, we can introduce the threshold level (T1) of the integrated edge value and produce fewer markers for the watershed process as shown in Fig.2.

Naturally, this optimum threshold (T1) may be varied according to the contents of images. Each threshold level of Edge H, Edge S and Edge I is assumed to be T1H, T1S and T1I respectively and also are assumed to be twice as large as each edge value.

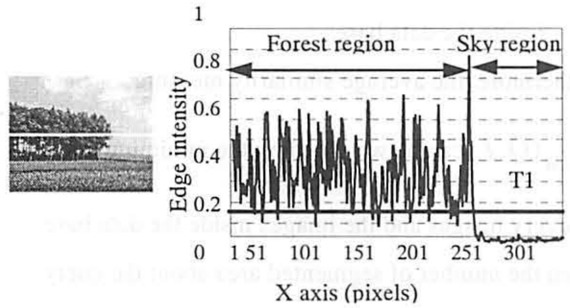


Fig.2 Example of the integrated edge

Then, we can derive the following equation.

$$T_{1H} = Avg(EdgeH) \times 2$$
$$T_{1S} = Avg(EdgeS) \times 2 \qquad (2)$$
$$T_{1I} = Avg(EdgeI) \times 2$$

Therefore, the new total edge value after each edge value modified by the threshold process is derived by the following equation (3).

$$Edgetoal = \alpha \times EdgeH' + \beta \times EdgeS' + \gamma \times EdgeI' \qquad (3)$$

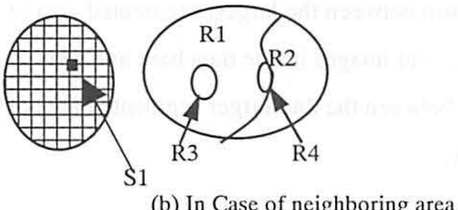
Where,

$$\alpha = Avg(EdgeH'), \beta = Avg(EdgeS'), \gamma = Avg(EdgeI')$$
$$\alpha + \beta + \gamma = 1, \{0 \le \alpha, \beta, \gamma \le 1\}$$

Finally, we can extract the modified total edge value from the color space diagram.

4 Regions Merging

After the watershed process is performed correctly, we can observe the plenty of small areas like the texture. In the case of the texture, we can set the threshold level (T2) when the ratio of area between a texture and an object is relatively small. Fig.3 (a) shows the merging procedure of textures.



(a) In case of texture

(b) In Case of neighboring area

Fig.3 Region merging methods

When the area of the region R4 is small comparing with the area of the region R2, we can set the threshold level (T3). In this case, each average hue level (Edge H) of the area, R2, R4, respectively can be derived and the nearest average hue level can be easily merged each other as shown in Fig.3 (b).

In the case of the area R3, we can also set the threshold level (T4) as the ratio of the area R3 to the area R1 when the area R3 is much smaller than the area R1 and then the area R3 can be merged into the area R1 as shown in Fig.3 (b).

5 Similarity Measure by Color Space Features

For color image retrieval systems, we need many image features, such as color features, textures, position of objects, etc.

For simplicity, we usually use the similarity measure by color space features. Therefore, color images must be converted into 15 colors as described in the previous section.

Now, we have to define the share of color C inside the area k, $h_k^I(c)$ as the following equation. [5]

$$h_k^I(c) = \frac{|\Lambda_k^I(c)|}{n \times m} \qquad (4)$$

Where, $n \times m$: pixels of whole image

Λ_k^I : set of k inside the image I

Then, the spatial coordinate b_k^I of the area k is expressed into the next equation.

$$b_k^I := (\overline{x_k}, \overline{y_k}) \qquad (5)$$

Where, $\overline{x_k} = \frac{1}{n}\frac{1}{\Lambda_k^I}\sum_{(x,y)\in\Lambda_k^I} x$

$$\overline{y_k} = \frac{1}{m}\frac{1}{\Lambda_k^I}\sum_{(x,y)\in\Lambda_k^I} y \qquad (6)$$

Similarly, we can calculate the similarity measure between query images s and the images t inside the data base especially in case of the smaller area of the segmented color space and also the nearest spatial coordinate reciprocally. Therefore, the similarity measure $f_{sim}(s,t)$ is derived by the next equation.

$$f_{sim}(k,l) = \frac{\sqrt{2} - D\left(b_s^Q, b_k^I\right)}{\sqrt{2}} \times \min \sum_{n=0}^{c} \left\{h_l^Q(n), h_k^I(n)\right\} \quad (7)$$

Where, $D(b_s^Q, b_t^I)$: Euclid distance between the spatial positions, b_s^Q and b_t^I

Then, we have to compare the similarity measure of each segmented area between query images s and images t inside the data base.

Then, we can derive several similarity measures $f_{sim}(s,t)$ according to the segmented images.

However, the numbers of segmented areas can be differed from the contents of color images. Therefore, the query images having the fewer number of segmented areas are compared with the corresponding segmented images inside the data base.

Then, we can get the following equation utilizing the smallest Euclid distance, $D(b_s^Q, b_t^I)$.

$$A(Q_s) \cong I_u \quad (8)$$

Where, $A(Q_s)$: segmented area s of the query image Q

I_u : Reciprocal segmented area u of the image I inside the data base

Furthermore, the average similarity measure $F_{sim}(Q,I)$ can be weighted by the minimum area of the query images and the images inside the data base. When the number of segmented area about the query images is j and the number of segmented areas about inside the data base is i, the average similarity measure, $F_{sim}(Q,I)$ can be derived by the following equation (9).

When i>j,

$$F_{sim}(Q,I) = \left\{\sum_{s=1}^{j} \min\left(\Lambda_s^Q, \Lambda_{A(Q_s)}^I\right)\right\} \times \frac{\sum_{s=1}^{j} f_{sim}\left(Q_s, A(Q_s)\right)}{j} \quad (9)$$

When i<j,

$$F_{sim}(Q,I) = \left\{\sum_{t=1}^{i} \min\left(\Lambda_{A(I_t)}^Q, \Lambda_t^I\right)\right\} \times \frac{\sum_{t=1}^{i} f_{sim}\left(A(I_t), I_t\right)}{i}$$

That is to say, every segmented area is put into the label and then compared with each labeled segmented area among query images and images inside the data base.

After all, the similarity measure between query images and images inside data base can be derived by the comparison between the largest segmented area of query images and images inside data base and also comparison between the 2nd larger segmented area of them in order.

6 Color Image retrieval system

We choose the above mentioned visual features extraction techniques for only applying to the natural scene. This kind of image retrieval system is likely to be applicable to the tourist information guide. The processing flow of color image system for the tourist information guide is shown in Fig.4.

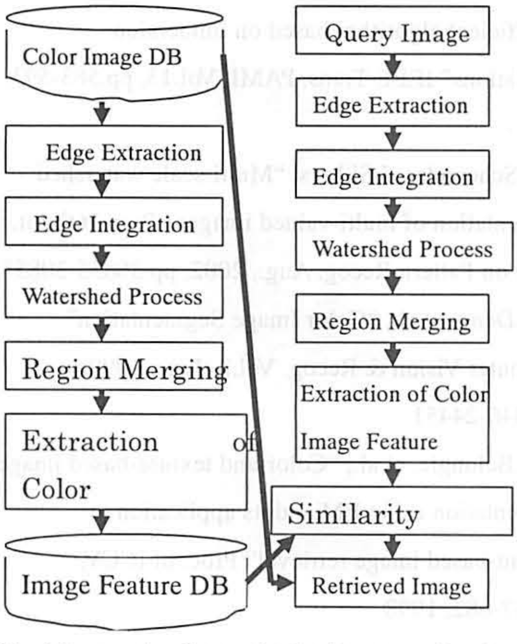


Fig.4 Processing flow of color image retrieval system using improved watershed algorithm

The processing flow of image retrieval system is described in the following steps.

(1) Color images are converted into H, S, I color space and every edge of H, S, I components are detected respectively. Then, the threshold level (T1) is selected heuristically depending on the contents of image. Finally, the integrated edge values of images are derived.

(2) The minima of the integrated edge values are adopted as markers for performing the watershed process. Then, the initial image segmentation is completed.

(3) From this integrated segmented images, every region of images is merged into the larger semantic area by means of size of area and hue information of images.

(4) The hue values of color images are reduced into 15 colors for the simplicity of computations. The spatial positions of areas are calculated by the equations (5), (6).

(5) Finally, the similarity measure between query images and the images inside the data base is derived by the equations (7), (8), (9).

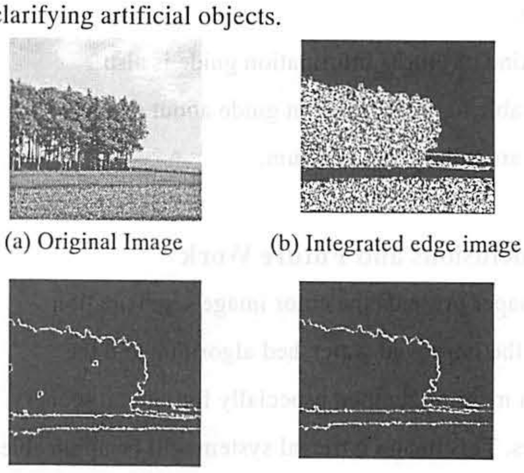
After all, we can retrieve the most similar image from the data base and display the similar images in order.

7 Experimental Results

We performed the experiments of image segmentation by the improved watershed method.

Firstly, we set the several threshold levels for the edge detection and merging the regions, T1=0.15, T2=0.005, T3=0.01 and T4=0.05 heuristically. And also, we assumed the weighting parameters of Edge H, Edge S and Edge I for the integrated edge, $\alpha = 0.3, \beta = 0.2, \gamma = 0.5$ respectively.

Then, we derived the good results of image segmentation as show in Fig.5 and believed that this image segmentation is suitable for natural scenery images. But, for complex images including the building and other artificial objects, we have to adopt the image processing techniques for eliminating and clarifying artificial objects.



(a) Original Image (b) Integrated edge image

(c) Initial image segmentation by watershed method (d) Segmented image after region merge

Fig.5 Segmented images after region merge

After all, we try to apply this image retrieval system for the tourist information guide as shown in Fig.6.

Usually, many tourist information guides utilize their natural scenery images in their top pages. These scenery images can be used for retrieving the tourist guide. Generally, the image data base stores these natural scenery images as shown in Fig.6 (b). This improved watershed algorithm can be applied to the color image retrieval system for the tourist information guide.

We can get the retrieved image about tourist information guide as shown in Fig.6 (c).

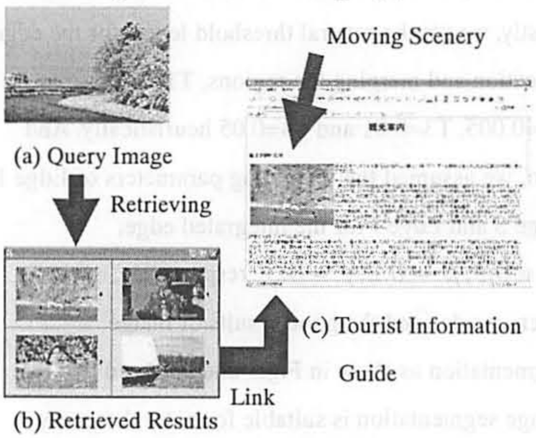


Fig.6 Tourist information guide

When you click the retrieved image, you can see the movie of the retrieved image using Windows Media Player.

This kind of tourist information guide is also applicable to the instruction guide about exhibits of many art gallery and museum.

8 Conclusions and Future Work

This paper presents the color image segmentation using the improved watershed algorithm and the region merging method especially for natural scenery images. This image retrieval system will be applicable to the tourist information guide and other instruction guides effectively.

In future, we have to consider the other image retrieval systems, such as e-commerce application, by introducing the semantic image retrieval systems for satisfying the user's needs.

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