A Real-time Segmentation Scheme for Continuous Color Images

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ABSTRACT

A real-time segmentation scheme for continuous color images is presented in this paper. The proposed scheme consists of two main steps: (1) seed searching and region growing, (2) region-based change detection. A new color representation model, RBG-Ellipse, is proposed. This color model is similar to the HSI representation. However, the transformation between RGB and RGB-Ellipse is linear. Therefore, we are able to take advantage of noise tolerance processing as well as the efficiency in dealing with color difference computation. By using the proposed segmentation scheme, we implemented applications, (1) intelligent networked visual monitoring system and (2) user interface for distance learning to highlight the value of the proposed scheme. Users can view the results through our web site, http://www.can.tku.edu.tw.

1. INTRODUCTION

A real-time segmentation scheme for continuous color images is presented in this paper. The proposed scheme consists of two main steps: (1) region search and growing, (2) region-based change detection. By using the proposed segmentation scheme, we implemented two applications, (1) intelligent networked visual monitoring system and (2) user interface for distance learning to highlight the value of the proposed scheme. Users can view the results through our web site, http://www.can.tku.edu.tw.

Object segmentation has been an active field of research for several decades. For single frame, object segmentation schemes can be classified into two categories: (1) boundary-based segmentation and (2) region-based segmentation. The discontinuities of color and/or luminance signals are used in the boundary-based edge detection to allocate the position of edge [1][8][12]. In the above case the design of filters affects the quality of the resulting edge detection. In the region-based segmentation techniques, the neighborhood pixels with similar color will be collected to form a region. This idea was further extended in [2,3], using not only color, but also texture information. In the above two approaches, the boundary-based segmentation scheme may fail to constitute a contour due to the smooth transition characteristic of the natural images. In other words, there are pixels which are not able to be classified into any particular region. This problem does not occur in region-based segmentation scheme. Both boundary-based and region-based segmentation schemes may divide the same object into different regions. In addition, different objects are allocated in the same region. Thus, a post-processing scheme is usually required to deal with these issues.

For sequence images object segmentation, object motion provides another dimension of information. In MPEG-1 and H.26x, motion estimation schemes are applied to identify the motion vectors. The coherent motion blocks are viewed as the same object [5][6]. Apart from blocks, the contour obtained in the edge detection process can also be used as the feature for motion estimation [4][10]. Furthermore, in the case of a moving camera, the estimated ego motion of the camera is usually used to compensate the object motion vector [9].

Change detection is another image processing technique used in our designs. The main purpose of this is to detect and to extract the different portions of two images. Based on the difference of the comparison unit, the change detection schemes are classified as pixel-based [7][11][13], block-based [13], and region-based approaches [13]. The pixel-based change detection scheme is sensitive to noise and ambiguous of the foreground and background occurs frequently. Block-based schemes are not suitable to deal with objects with arbitrary shapes. The region-based approach may overcome this difficulty. The regions obtained from edge detection are used as a comparison unit. Therefore, it has the advantage of extracting arbitrary shapes in an image. Both block-based and region-based change detection schemes outperform pixel-based change detection scheme in dealing with noise.

A new color representation model, RBG-Ellipse, is proposed. This color model is similar to the HSI representation. However, the transformation between RGB and RGB-Ellipse is linear. Therefore, we are able to take the advantages in noise tolerance processing as well as the efficiency in dealing with color difference computation. The remaining parts of this paper are organized as follows. The proposed RGB-Ellipse color model is presented in Section 2. We describe the color difference computation scheme and indicate the strength and weakness of this model. Region based segmentation is shown in Section 3. We show the corresponding design steps in detail. Two applications that make use of the proposed approaches are illustrated. And conclusions are given in Section 4.

2. RGB-Ellipse Color Difference Model

The transformation between RGB to RGB-Ellipse (XYZ) is illustrated in Fig. 1. The vector (1,-1,0) is chosen as the rotation axis. Using the right-hand rotation rule, the vector (1,1,1) in the RGB space rotates to the direction parallel to (0,0,1) in the XYZ space. In this manner, the Z-axis in the RGB-Ellipse model represents the luminance and X and Y axis represent the chroma, respectively. The above transformation can be stated as Eq. (1).

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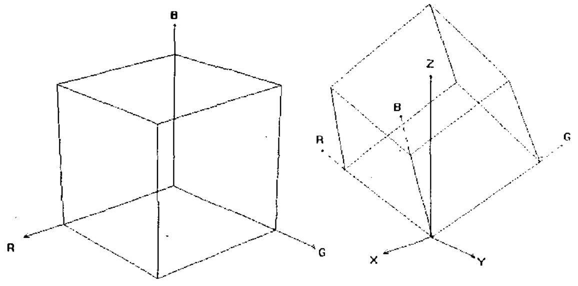
$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} \frac{1}{2}(1-\cos\theta)+\cos\theta & -\frac{1}{2}(1-\cos\theta) & -\frac{1}{\sqrt{2}}\sin\theta \\ -\frac{1}{2}(1-\cos\theta) & \frac{1}{2}(1-\cos\theta)+\cos\theta & -\frac{1}{\sqrt{2}}\sin\theta \\ \frac{1}{\sqrt{2}}\sin\theta & \frac{1}{\sqrt{2}}\sin\theta & \frac{1}{\sqrt{2}}\sin\theta \end{bmatrix} \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

$$\cos\theta = \sqrt{3}/3 \ , \ \sin\theta = \sqrt{6}/3$$



a. RGB color space b. RGB-Ellipse color space

Fig.1 The transformation between the RGB space and the RGB-Ellipse (XYZ) color space

After plugging in the corresponding coefficients in the above equation, Eq. (1) can also be represented as Eq. (2)

$$\begin{cases} X = 0.789\times R - 0.211\times G - 0.577\times B \\ Y = -0.211\times R + 0.789\times G - 0.577\times B \\ Z = 0.577\times (R+G+B) \end{cases} \quad (2)$$

From Eq. (2), it is clear that the RGB-Ellipse model is similar to the HSI color representation. The computation of the color difference in this paper is based on the above equation as shown in Eq. (3). Note that Eq. (3) also forms an ellipsoid Just Noticeable Difference (JND) region. The coefficients a, b, and c determine the shape of the corresponding ellipsoid. These coefficients also relate to the allowable tolerance in the XYZ axis.

$$\Delta E^* = \sqrt{\frac{\Delta X^2}{a} + \frac{\Delta Y^2}{b} + \frac{\Delta Z^2}{c}} \quad (3)$$

In this paper, there are two cases where we apply the RGB-Ellipse model to compute the color difference:

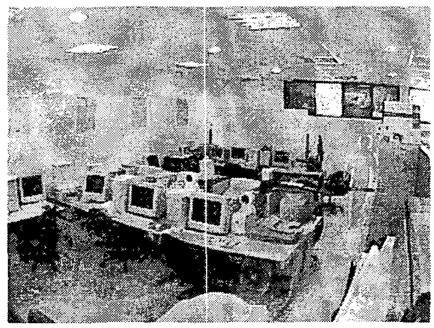
- Comparison: To detect the differences between different images, the shadow cannot be treated as a change. In order to have more tolerance, the ellipsoid JND needs to extend along the Z (illuminant) axis.
- Region growing: The shadow is not part of the object. To separate object and shadow, the ellipsoid JND needs to squeeze along the Z-axis.

The captured signals of CCD camera contain noise. Assuming the noise distribution is Gaussian, we modify Eq. (3) as follows.

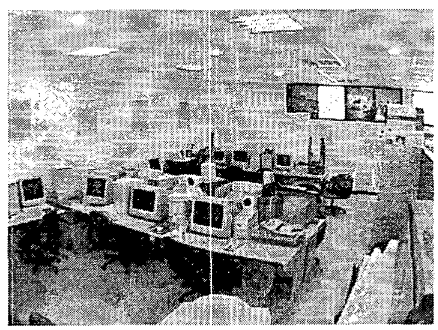
$$\begin{cases} \Delta E^* = \sqrt{\frac{\Delta X^2}{a^*} + \frac{\Delta Y^2}{b^*} + \frac{\Delta Z^2}{c^*}} \\ a^* = \left(\frac{\tau + k_x}{\tau}\right)^2 \times a \\ b^* = \left(\frac{\tau + k_y}{\tau}\right)^2 \times b \\ c^* = \left(\frac{\tau + k_z}{\tau}\right)^2 \times c \end{cases} \quad (4)$$

where τ is a predetermined threshold of the color difference ΔE^*. k_x, k_y and k_z denote the standard derivation in XYZ axis, respectively.

a. F_B b. F_n



c. RGBEllipse (1:1:1) $\tau = 15.0$



d. RGBEllipse (1:1:4) $\tau = 15.0$

Fig. 2 Comparison of shadow elimination and noise tolerance

A testing video is used to verify the above scheme. The results of shadow elimination and noise tolerance of RGB-Ellipse model are shown in Fig. 2. Fig. 2 (a) and (b) show the background image of the monitoring site and the present image, respectively. RGB-Ellipse(1:1:1), and RGB-Ellipse(1:1:4) are shown in Fig. 2 (c), and (d), respectively. The RGB-Ellipse has the advantage in dealing with noise.

3. Real-time Object Segmentation Scheme

The proposed image segmentation scheme consists of two main stages, namely, (1) region search and growing and (2) region-based change detection. Note that the segmentation scheme designed here aims to do object segmentation automatically under the changes of lightness and background.

3.1 Region search and growing

Region-based segmentation is an intuitive approach. The main idea is that the neighborhood pixels are merged, if their colors are similar. By following the above idea to form a region, first the growing seeds need to be determined. The selection of the region growing seeds is the key issue of the success in the proposed segmentation process. There are two issues that need to be considered in the seed searching and selection process, (1) the computation time and (2) the background update. For an image resolution 640x480, thousands of regions may be formed in arbitrary shapes. As a result, the object segmentation process becomes very time-consuming. However, only a few objects are of interest in an image. If we are able to allocate the seed of region-growing inside the corresponding object, the result obtained in the region-growing regions are only the regions in the object. Thus, the computation time is saved. In some applications, the background image is difficult to obtain without any disruption. In other words, the captured images always contain moving objects that may not be of interest. The motion-based seeds searching are designed to solve this issue.

The detailed motion-based seed searching algorithm is shown in Fig. 3. The subroutine ColorDiff() computes the color difference mentioned in Section 2. If the return value is TRUE, it shows color changed in the corresponding point. And this point is selected as seed and put in the SeedSet.

```
Algorithm SeedSearch

Set SeedSet = EMPTY
for I =1 to IMAGEWIDTH
  for J=1 to IMAGEHEIGHT
    if ColorDiff( F_{n-1}(I, J), F_n(I, J) ) is TRUE
          and ColorDiff( F_n(I, J), F_{n+1}(I, J) ) is TRUE then
      add point(I, J) to SeedSet
    end if
  end loop
end loop
```

Fig. 3 Motion-based seed searching algorithm

After the seeds are allocated, we proceed the region growing process, It starts from upper left to right in sequence. If the color difference is within the predetermined threshold, the new pixel is added to the same region.

3.2 Region-based change detection

In some cases, only applying the region growing algorithm may lead to false results, such as (1) regions belonging to the background F_B are treated as being in the foreground F_n and (2) regions include the shadowed areas. Therefore, change detection is used to eliminate the above mentioned problems.

The flow chart of region based change detection is shown in Fig. 4. First, the resulting regions in F_n are projected to F_B, and then the mean color values in the corresponding regions are computed. Second, we compare the color difference by using Eq. (4). If the difference is greater than a predetermined threshold, the resulting region is classified as foreground. Otherwise, it belongs to background.

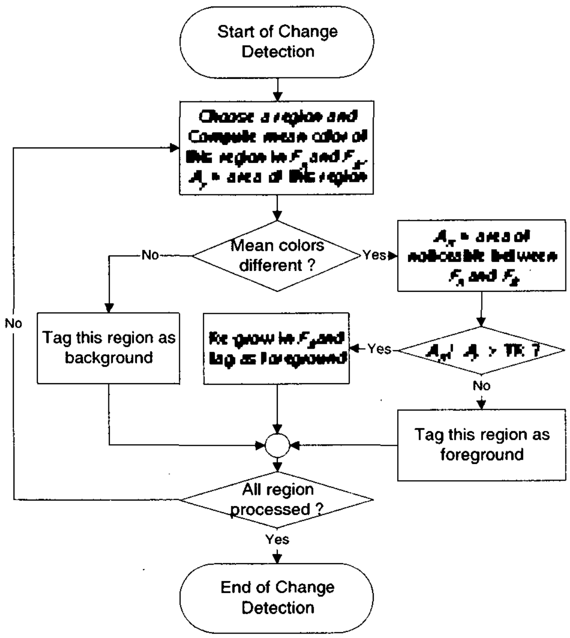


Fig. 4 The flowchart of change detection

3.3 Applications

We implemented two systems by using the proposed segmentation algorithm. One is the intelligent networked visual monitoring system and the other is user interface for distance learning. In both cases, the information obtained in the object segmentation is used to track the intruders and teacher motion, respectively. Readers may access our web site to view the results.

4. EXPERIMENT RESULTS

4.1 Segmentation results

A complex background of an indoor 640x480 full color test video is shown in Fig. 2. As we described before, the frames with interval of 300ms are processed in our segmentation algorithm. Note that the processing rate is different from the sampling rate. The segmentation results of the proposed scheme are shown in Fig. 5. The results are acceptable in many real-time applications, such as surveillance. However, shadows and holes may still exist in some frames, post-processing may be required to obtain clean-cut objects.

Fig.5 Segmentation results

4.2 The Computation time of the algorithm

The plot of computation time in different machines and platforms for the proposed algorithm is shown in Fig. 6. The processing rate achieves 3fps in the Pentium III 500 machine.

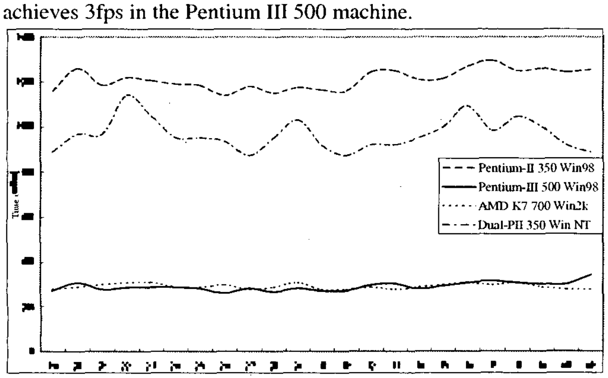


Fig.6 Computation time

5. CONCLUSIONS

Object segmentation plays a crucial role in modern image and video processing. The results of this scheme can be applied in many areas. In this paper, we design a real-time segmentation scheme for continuos color images. The segmentation scheme consists of two main stages, namely, (1) region-based searching and growing and (2) region-based change detection. In order to compute the color difference in our scheme, we propose a color model, RGB-Ellipse. The experimental results show the proposed color model have the advantage in terms of noise tolerance and computation efficiency. In addition, we implemented two applications by making use of the design schemes. Users can view the result from our web site, http://www.can.tku.edu.tw.

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