Paper

Image Segmentation Using HIS Color Space and Considering Pixel Block Properties

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In this paper, we propose a novel approach to segment image using HIS color space and considering pixel block properties. HIS color space is used to express the pixel color information. Considering the hue value will be very sensitive when the saturation and intensity values are low, the color purity is used as the weight on the hue value. This method considers not only the pixel properties, such as color and position, but also the pixel block properties. An image is divided into blocks. For each block, the mean and variance values are calculated. The variance value can be seen as the pixel block property that expresses the variation of pixels in the block. Based on the block mean, the image is segmented with the region growing approach. The pixels in the small objects obtained from the image segmentation will be merged into the large object by the decision of vector distance together with the pixel position information. The experimental results confirm this approach is useful and suitable for many kinds of images.

Key words: image segmentation, HIS color space, color purity, pixel block properties

1. Introduction

Image segmentation is the fundamental of image analysis and pattern recognition. It is also used to compress moving picture in MPEG-4 standard. In computer vision, segmentation is to get the appropriate representation of the meaningful objects in the image with specific properties of interest. It can be considered as a pixel labeling process in the sense that all the pixels with similar properties are assigned the same label. Many techniques have been proposed to deal with the image segmentation problem. The most popular used techniques are clustering based, edge based and region based techniques. When using clustering based technique [1][2], the image is segmented with the color information histogram or some other theoretic criteria. However, it is difficult to decide the number of meaningful objects. When the number is assumed to be known, sometimes, an object consists of separate parts. Edge based techniques detect the image edges and represent the boundaries of image objects. Many methods have been used to make the edges to be connective and one-pixel wide [3][4]. But if the variation of some part in the image is vigorous, lots of small objects appear in the segmentation result. In the region based technique [5][6], pixels are collected according to a certain decision rule, for example, the similar color. However, if there is noise or area like texture in the image, this technique can not work well. On image segmentation, there are other techniques, such as Markov random field and fuzzy theory [7]. They are only suitable for some specific images.

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All the techniques above consider only the pixel properties or the relationship between pixel and its neighbors. The pixel block properties are considered recently [8]. In this paper, we propose a novel image segmentation approach considering not only the individual pixel properties but also the pixel block properties. This approach combines the region growing method based on block mean and variance with the decision of vector distance together with the position information when merging small objects. HIS color space is used as the pixel color property. Considering the sensitivity of hue value when the color purity is low, the color purity is used as the weight on the hue value. The image to be segmented is divided into blocks at first. The block variance value is regarded as the pixel block property expressing the variation. Small objects are merged by the decision of vector distance considering the relative position information to make all the pixels be connective in a single meaningful large object.

The remainder of this paper is organized as follows. In Section 2, we will introduce the HIS color space and discuss the color purity. The image segmentation process is illustrated in Section 3. The experimental results are shown in Section 4. Finally, we will draw a conclusion is Section 5.

2. Color Space

From the original image, we can get the pixel RGB data, which values are from 0 to 255. The combination of R, G and B data expresses the pixel color information, for example, yellow. But the saturation or intensity of the yellow can not be obtained from RGB data directly. To grasp the robust observation from image, the RGB data is transformed to the data in the HIS color space. There are many formulas to transform RGB data to HIS data. We use the following formula.

Let I_{max} = max(R, G, B) and I_{min} = min(R, G, B), set

$r = (I_{max} - R) / (I_{max} - I_{min})$,
$g = (I_{max} - G) / (I_{max} - I_{min})$,
$b = (I_{max} - B) / (I_{max} - I_{min})$.

If $R = I_{max}$ then $H = \pi * (b - g) / 3$;
If $G = I_{max}$ then $H = \pi * (2 + r - b) / 3$;
If $B = I_{max}$ then $H = \pi * (4 + g - r) / 3$, where the value of H should plus 2π if $H < 0$.

$I = I_{max} / 255$.
$S = 1 - I_{min} / I_{max}$.

The hue values are from 0 to 2π. Both the saturation and intensity values are from 0 to 1. From the transform fomula, if the I_{max} is very close to the I_{min}, the hue value will be very sensitive. A little variation of RGB results in the large variation of the hue value. For example, when (R, G, B) = (43, 40, 37), the hue value is about $\pi/6$, but when (R, G, B) changes to (43, 40, 39), though we can not see any change in color, the hue value becomes about $\pi/12$. So the color purity, P, should be considered.

$$P = S * I = (I_{max} - I_{min}) / 255$$

Figure 1 shows red color that the hue value is 0 with different intensity and saturation values. If the color purity is low, the hue value does not match the color precisely as its being observed. In the extreme case, when the saturation value is 0, it is seen as gray with different intensity, and when the intensity value is 0, the color is seen as black no matter what the hue value is.

So the hue value is not suitable to be used directly in image segmentation. When the color purity is samller than 0.3, in Figure 1, the color is seen like gray scale. In this case, we use the color purity as the weight on the hue value to decrease the bad influence due to low purity. The hue value H is changed into H', and

$$H' = P * H.$$

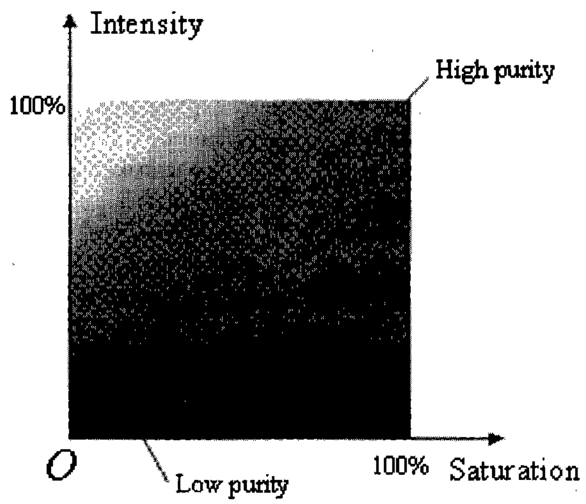


Fig. 1. Variation of color purity.

3. Image Segmentation

Region growing approach is used in image segmentation popularly to merge pixels with similar properties. The traditional region growing segmentation approach checks all the pixels in the image. If there is some noise in the image or the color information variation of some pixels is vigorous, there must be many small meaningless objects in the segmentation results. We improve the region growing approach, which considers the pixle block properties and is based on the mean and variance of blocks. The mean calculation can decrease the influence of the pixels with abnormal or vigorous variation. The variance value can be regarded as the property of the block. If the variance value is large, it expresses that the variation of the pixles color information in the block is vigorous.

According to the original image size, the image is divided into blocks with suitable size M * N. The block size should only divide the image size, no matter what it is a square or a rectangle. So it can be dealt with easily. The mean and variance of each block are calculated with

$$Mean_x = \frac{1}{M*N} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} p_x(i,j)$$

$$Variance_x = \frac{1}{M*N-1} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (p_x(i,j) - Mean_x)^2$$

$$x \in (H, I, S)$$

where $p_x(i,j)$ is the value of hue, intensity and saturation of the pixel whose position in the image is (i, j). The divisor M * N - 1 instead of M * N in calculating variance is a statistical problem that is explained in [9] in detail. After the calculation of block mean and variance, the rest process is shown as follows:

Ⅰ) Segment the image with the region growing approach based on block considering the pixel block properties.
Ⅱ) Merge the small objects into large objects by the decision of vector distance together with position information.

In Step Ⅰ), the histogram is used to decide if the variance of intensity in a block is large or not. The large variance of intensity expresses that the variation of the pixels in the block is vigorous, which means that the block is rough. The block with large variance is maybe on the boundary or in some object that has the roughness property. To distinguish these two cases, the area density, which is calculated with the number of blocks with large varaince dividing the total number of blocks in an area, is examined. If the area density is high, the blocks in this area are in an object. Otherwise, they are on the boundary. The blocks with the large variance in the high density area can be regarded as an object due to the roughness property. The other part, which consists of blocks whose variance is small or decided on the boundary is segmented with the region growing approach based on block. The process is shown as follows:

a) Set a mark array with all elements being 0.
b) Let i = 1, label the first block with i in the mark array.
c) Check all the blocks that are not labeled and are adjacent to the labeled blocks. If the mean difference of two adjacent blocks is small and the variance of the non-labeled block is small, label the non-labeled block with i.
d) In step c), if there is no block satisfying the condition, let i = i + 1. Label any non-labeled block with i.
e) Repeat step c) and d) until all the blocks are labeled.

After segmentation, to avoid the unnecessary sharp angle appearing in the objects obtained, the blocks that belong to a large object but are adjacent to another object are set to be a small object. The small objects will be merged into large objects in Step II). When merging small objects, the position relationship is checked at first. As shown in Figure 2, if a small object is in a large object or is surrounded by a large object from three directions, the small object should be merged into the large object.

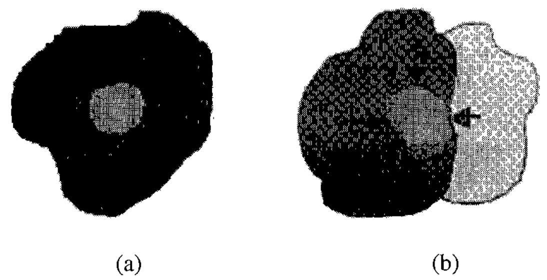


Fig. 2. The relationship between objects. (a) A small object in a large object. (b) A small object surrounded by a large object from three directions.

If there is no surrounding position relationship between the small object and the large object, the small object will be merged by the decision of vector distance. In this case, all the pixels in small object are checked individually but not the block. Together with comparing the vector distance calculated with the hue, intensity and saturation values like the traditional vector quantization method, the position information of a pixel is paid much attention to. It is illustrated with Figure 3.

In Figure 3, ***p*** is a pixel in the small object should be merged into the large objects marked with **A** to **F**. A line with the pixel ***p*** as the original point and with the long enough radius scans the whole image like radar. If the pixels on the line that is from the original point ***p*** to the pixel on the boundary of a large object are all in the small objects, pixel ***p*** probably belongs to the large object. If no such line exists, pixel ***p*** should not be merged to that large object. Pixel ***p*** probably belongs to the three large objects of **A**, **D** or **E**. Because it is possible to reach these three large objects from pixel ***p*** through a line directly. Pixel ***p*** should not be merged into objects of **B**, **C** and **F**. For example, to reach large object **B** from pixel ***p*** through a line, it must cross large object **A**. In this case, it is not suitable to merge pixel ***p*** into large object **B**.

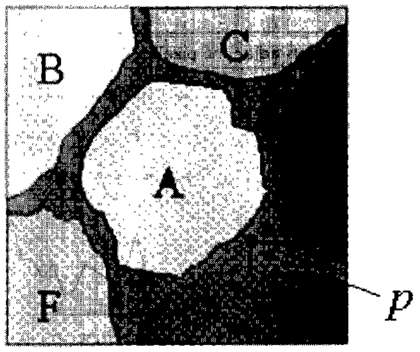


Fig. 3. The relative position of pixel ***p*** and large objects.

4. Experimental Results

To confirm the image segmentation approach we proposed, the standard image Claire is used at first. The original image is shown in Figure 4.

The image size is 310 * 276 pixels and the block size is set as 5 * 6 pixels. It is important to decide whether the block variance value is large or not. We check the maximum intensity difference in each block, which is the difference between the maximum intensity and the minimum intensity in the block. The average of intensity differences between adjacent pixels in each block is also calculated. And the minimum average is selected as the average difference of the block. For the blocks with the same variance value, the minimum values of the two kinds of difference explained above are used. In Figure 5, the purple curve expresses the maximum difference of pixels and the blue curve expresses the average of differences between adjacent pixels. We only show the data until the variance value of 50 in the figure because the data of the variance value larger than 50 has the same trend as that smaller than 50. From this figure, we can see when the block variance value is 18, the first peak appears in both the curves of difference between adjacent pixels and maximum difference. That is to say, when the block variance value is 18, the variation of pixels intensity in the blocks is vigorous. It can be considered that the block is rough enough when the block variance value is 18. So on this image, we decide that if the variance value is larger than 18, the variance value is large.

Fig. 4. The original image of Claire.

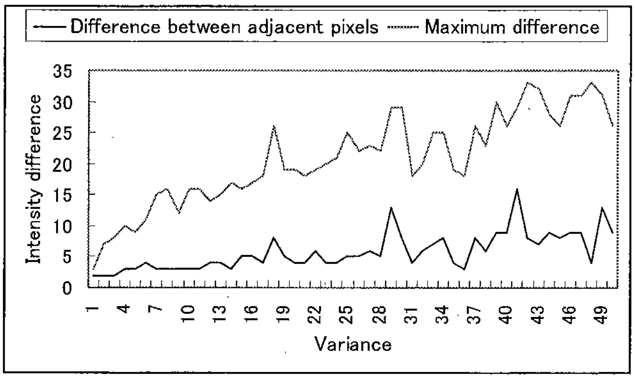


Fig. 5. Pixel intensity difference for different variance.

Fig. 6. The segmentation result with region growing approach based on block.

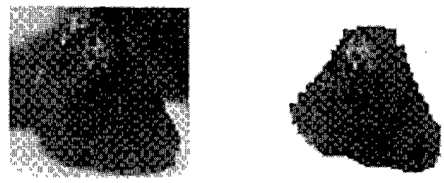
The result after segmenting the image with the region growing approach based on block is shown in Figure 6. The large objects are expressed in black, and the small objects are expressed in white. When segmenting the image with the region growing approach based on block, the threshold to decide whether the block mean difference is large or not is set as 5. All the rest experimental results shown in this paper are obtained with the thresholds being 5 when the images are segmented.

After merging small objects, the head object segmented from Image Claire is shown in Figure 7. Though the eyes and the mouth are different from the face in the color information, they are all the small objects in the large head object. So they are merged into the head object. There are also some pixels are close to the face in the color information, but according to the decision of relative position information, they are not merged into the head object.

We also test the image of strawberry. The original image and the strawberry object is shown in Figure 8. The surface of strawberry is rough. If it is segmented with the traditional region growing approach based on pixel, there will be many small objects in the result and it is difficult to obtain the intact strawberry object. Using the approach we proposed based on block, the roughness is regarded as the pixel block property. The block mean calculation can decrease the influence of variation, so the region growing process can be done well. Because of considering the color purity, the shadow is separated from the strawberry object. Because the blocks on the object boundary are dealt with specially when segmenting, there is no unnecessary sharp angle in the result. The object boundary is very nature.

At last, we show the segmentation result of image Mandrill in Figure 9. The objects are separated by black curves. On the part of the fur, all the hue, intensity and saturation values vary vigorous. The variation is seen as the pixel block property, so the fur is an object. The eyes are in the fur object and are small, they are merged into the fur object.

Fig. 7. The head object of Claire.



(a) (b)

Fig. 8. (a) The original image of strawberry.
(b) The strawberry object.

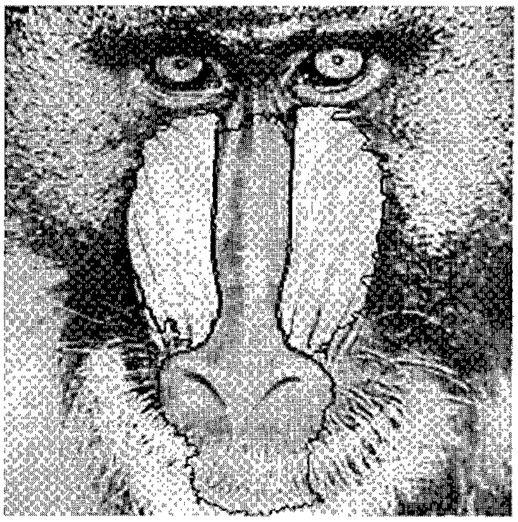


Fig. 9. The segmentation result of image Mandrill.

5. Conclusion

In this research, we proposed the image segmentation approach with region growing method based on block considering the pixel block properties. The small object is merged by the decision of vector distance together with the relative position information. When segmenting image, the color purity is as the weight on the hue value due to the sensitivity of hue value when the color purity is low. To obtain the pixel block properties, the image is divided into block with suitable size at firts. The block mean calculation can decrease the bad influence due to the noise or abnormal variation. The mean value is regarded as the pixel block color property. The block variance value expresses if the variation is vigorous or not. It is regarded as the pixel block roughness property. If the density of blocks with large variance value in an area is high, these blocks can be regarded as a part of an object due to roughness property. When merging small objects, the relative position information is used to assure that all the small objects can be merged efficiently and all the pixels in an object are consecutive. From experiments, our approach is confirmed to be able to segment many kinds of images very well.

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References

(1) T. Yamazaki : "A Study of Color Image Segmentation Based on a Multi-dimensional Histogram", *Technical Report of IEICE*, OFS2000-37, IE2000-43, pp.9-14 (2000-9)

(2) D. A. Langan, J.W. Modestino, and J. Zhang : "Cluster Validation for Unsupervised Stochastic Model-Based Image Segmentation", *IEEE Trans. Image Processing*, Vol.7, pp.180-195 (1998-2)

(3) G. A. Hewer, C. Kenney, and B. S. Manjunath : "Variational Image Segmentation Using Boundary Functions", *IEEE Trans. Image Processing*, Vol.7, pp.1269-1282 (2000-9)

(4) G. Iannizzotto and L. Vita : "Fast and Accurate Edge-Based Segmentation with No Contour Smoothing in 2-D Real Images", *IEEE Trans. Image Processing*, Vol.9, pp.1232-1237 (2000-7)

(5) T. N. Jones and D. N. Metaxas : "Image Segmentation Based on the Integration of Pixel Affinity and Deformable Models", *Proc. CVPR'98*, Santa Barbara (1998-6)

(6) T. N. Tilton : "Image Segmentation Based on the Integration of Pixel Affinity and Deformable Models", *Proc. CVPR'98*, Santa Barbara, (1998-6)

(7) T. Sasaki, Y. Hata, and Y. Ando : "Fuzzy Rule-based Approach to Segment the Menisci Regions from MR Images", *Proc. SPIE Medical Imaging*, Vol.3661, pp.258-263 (1999)

(8) Z. Chi, T. Kimura, K. Yamauchi, and K. Hatakeyama : "Image Segmentation Using HIS Color Space Based on Block Mean and variance", *Proc. ICYCS'2001*, Vol.1, pp.214-218, Hangzhou China (2001-10)

(9) G.W. Snedecor and W.G. Cochran, "Statistical Methods", Seventh Edition, The Iowa State Univ. Press (1980)

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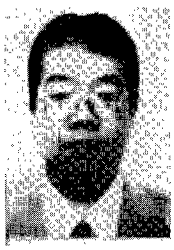

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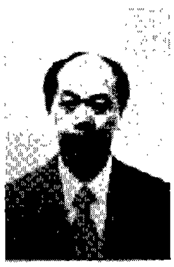

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