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Image Segmentation Considering Intensity Roughness and Color Purity*

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Abstract: A novel method to segment image is proposed considering the intensity roughness and the color purity. HIS color space is used to express pixel color information. Not only the pixel properties but also the pixel group properties are considered. An image is divided into blocks. For each block, the mean and variance values can be seen as the pixel group properties. Because the hue value will be very sensitive when the intensity and saturation values are small, the color purity is used as the weight on the hue value. The image segmentation is done with the approach of the combination of region growing based on block and vector quantization. The experiments confirm this method is suitable for many kinds of images.

Key words: image segmentation; HIS color space; block mean and variance; intensity roughness; color purity

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, 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 cannot work well. On image segmentation, there are other techniques, such as Markov random field and fuzzy theory[5]. They are only suitable for some specific images.

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All the techniques above consider only the pixel property or the relationship between pixel and its neighbors. The pixels group property is considered recently[6]. In this paper, a novel image segmentation method is proposed considering not only the individual pixel property but also the pixels group property. This method combines the region growing method based on block mean and variance with the decision of vector distance when merging small objects. The image to be segmented is divided into blocks at first. The block variance value is regarded as the pixels group property expressing the variation. HIS (hue, intensity, saturation) color space is used as the pixel property. Considering the sensitivity of the hue value when the color purity is low, the color purity is used as the weight on the hue value. 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 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. Though the RGB data expresses the pixel color information, all the properties of the pixel cannot 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 $I\text{max}=\max(R,G,B)$ and $I\text{min}=\min(R,G,B)$,

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

If $R=I\text{max}$ then $H=\pi\times(b-g)/3$; If $G=I\text{max}$ then $H=\pi\times(2+r-b)/3$; If $B=I\text{max}$ then $H=\pi\times(4+g-r)/3$, where if $H<0$, the value of H should plus 2π. $I=I\text{max}/255$, $S=1-I\text{min}/I\text{max}$.

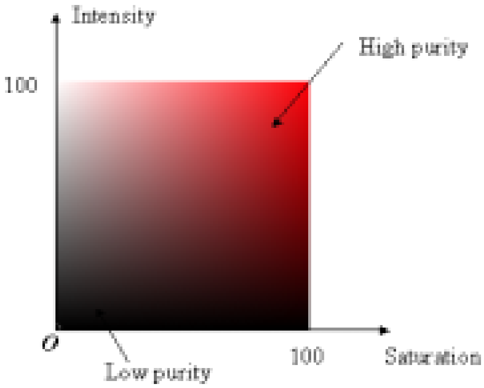


Fig.1 Variation of color purity

From the transform formula, if the Imax is very close to the Imin, the hue value will be very sensitive. A little variation of RGB results in the large variation of the hue value. So the color purity, P, $P=S\times I=(I\text{max}-I\text{min})/255$, should be considered. 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. It is not suitable to be used directly in image segmentation. In this case, we use the color purity as the weight on the hue value to decrease the bad influence due to low purity. When the color purity is smaller than 0.3, in Fig.1, the color is seen like gray scale. The hue value H is changed into H', and $H'=P\times H$.

3 Image Segmentation

The traditional region-growing segmentation approach checks all the pixels in the image. This makes the complexity of computation very big and needs very large memory. 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 is based on the mean and variance of blocks. The mean calculation can decrease the influence of the pixels with abnormal and vigorous variation. The variance value can be regarded as the property of a block. If the variance value is large, it expresses the variation of the pixels 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 mean and variance of each block are calculated with

where $p(i,j)$ is the value of hue, intensity and saturation of the pixel whose position in the image is (i,j). The divisor

$$Mean = \frac{1}{M*N}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1} p_{i,j}, \qquad Variance = \frac{1}{M*N-1}\sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\left(p_{i,j} - Mean\right)^2,$$

$M*N-1$ instead of $M*N$ in calculating variance is a statistical problem that is explained in Ref.[7] in detail. The segmentation process is shown as follows:

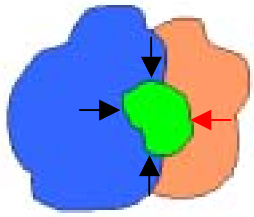
a) Divide the image into blocks with suitable size and calculate the mean and variance for each block.

b) Segment the image with region growing approach based on block considering the pixel group property.

c) Merge the small objects into large objects by the decision of vector distance.

In Step a), the block size should only divide the image size no matter if it is a square or a rectangle. So it can be dealt with simply. In Step b), the histogram is used to decide if the variance of intensity 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. It can be regarded as a property of the block. 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 variance dividing the total number of blocks in an area, is examined. If the area density is high, which is larger than 0.5, 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 variances are small or decided on the boundary, is segmented with the region growing approach based on block. 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 c). When merging small objects, the position relationship is checked at first. As shown in Fig.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. When segmenting, objects are labeled with different numbers. The size of an object can be known with counting the number. For the small object, the relationship between the adjacent object or objects can be decided with checking the numbers around it. 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 are checked individually but not the block as a pixel group. The position information of a pixel is paid much attention to, together with comparing the vector distance with the hue, intensity and saturation values like the traditional vector quantization method. It is illustrated with Fig.3.

(a) A small object in a large object



(b) A small object surrounded by a large object from three directions

Fig.2 The relationship between objects

In Fig.3, p is a pixel in the small object and should be merged into the large objects marked with A to F. A line with the pixel p as the original point and long enough 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. In Fig.3, pixel p probably belongs to the three large objects of A, D and 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 the large object A. It will lead to a result that some pixels belong to an object but they are not connective and be seen as two objects. It is assumed that all the pixels belonging to an object must be connective. So, in this case, it is not suitable to merge pixel *p* into large object B.

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 Fig.4. The image size is 310×276 pixels and the block size is set as 5×3 pixels. The histogram of intensity variance is shown in Fig.5. From this figure, when the variance is larger than 18, the number of block for each variance value varies little. On mathematics, variance 18 means the difference between the intensity mean and the pixel intensity is about 4. So on this image, it is decided that if the variance value is larger than 18, the variance value is large. To decide two adjacent blocks belonging to a same object, the threshold for the mean value is set as 5.

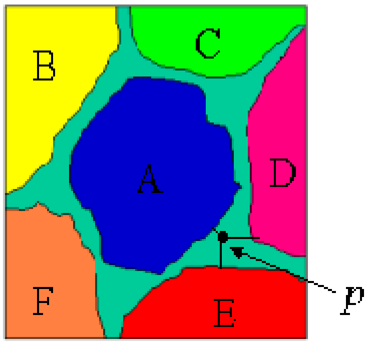
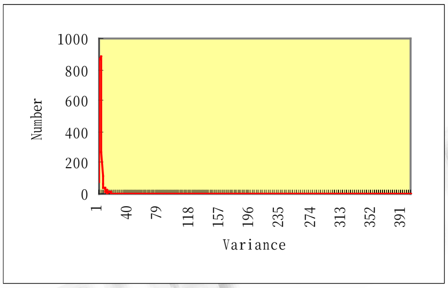
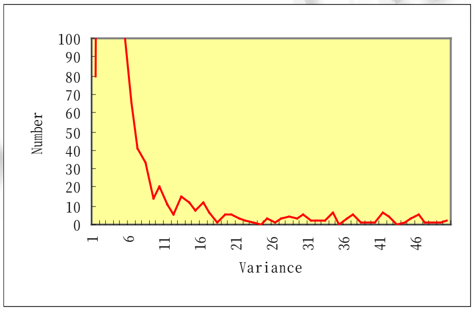


Fig.3 The relative position of pixel *p* and large objects

Fig.4 The original image of Claire



(a) The intensity variance histogram of image Claire



(b) The expanded intensity variance histogram

Fig.5

The result after segmenting the image with the region growing approach based on block is shown in Fig.6. The black part is large object and the white part is small object.

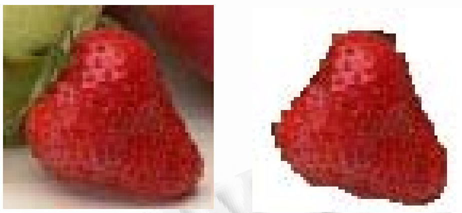
The head object segmented from image Claire is shown in Fig.7. Though the eyes and the mouth are different from the face in the color information, they are all the small objects in the large head object. So they are merged into the head object.

We also test the image of strawberry. The original image and the strawberry object are shown in Fig.8. The image size is 105*100 pixels and the block size is set as 5*4 pixels. 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 property. The calculation of block mean 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, there is no unnecessary sharp angle in the result. The object boundary is very natural.

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

Fig.7 The head object

We also show the segmentation result of image Mandrill in Fig.9. The image size is 256×256 pixels and the block size is 4×4 pixels. The objects are separated by black curves. On the part of fur, all the hue, intensity and saturation values vary vigorous. Only seeing the variation as the property, the image can be segmented. If the image is segmented with the traditional region-growing method, there must be many small objects in the result because of the roughness. For testing the multi-target image, the standard image of Parrots is used. The image size is 256×256 pixels and the block size is 4×4 pixels. The segmentation result is shown in Fig.10. Two parrots and the background are segmented clearly.



(a) Original image of strawberry (b) Strawberry object

Fig.8

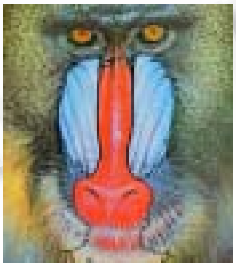


Fig.9 Segmentation result of Mandrill

Fig.10 Segmentation result of Parrots

5 Conclusion

In this research, we proposed the image segmentation approach with region growing method based on block. The small object is merged with the decision of vector distance considering the relative position information. When segmenting image, the color purity is as the weight on the hue value considering the sensitivity of hue value when the color purity is low. The calculation of block mean can decrease the bad influence due to the noise or abnormal variation. Not only the color information of each pixel but also the property of the pixels group are considered. The block variance value expresses if the variation is vigorous or not. If the density of block 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 segment many kinds of images very well.

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考虑到亮度变化和颜色纯度的图像分割法

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摘要: 提出了一种新的考虑到亮度变化和颜色纯度的图像分割方法.使用 HIS 颜色空间来取得象素的颜色信息.当饱和度和亮度值较低时,色彩值会非常敏感,用颜色纯度作色彩值的加权值.不但考虑了像素的属性,还考虑了像素群的属性.图像先被分成块,块的平均值和方差值作为像素群的属性.用基于块的领域扩张来进行图像分割.用向量距离和相对位置信息把小的对象合并到大的对象中.实验结果证明,该方法适用于多种图像.

关键词: 图像分割;HIS 颜色空间;块的平均和方差;亮度变化;颜色纯度

中图法分类号: TP391 文献标识码: A