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Edge Detection Algorithm based on Color Space Variables

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Abstract

In view of the large number of environmental influence factors in complex and varied backgrounds, a color image feature extraction method based on color space variables is proposed. According to the method of maximum variance between classes, color space variable values are used to classify images, and filter operators are used to denoise different types of images. The preprocessed image again calculates the foreground segmentation threshold and combines the canny operator, the multiscale theory, and the morphological operator to extract the edge. The results show that this method can effectively process various background color images and provide a new idea and method for intelligent processing of color images.

Keywords: maximum variance between classes; color space; edge detection; edge feature extraction

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1. Introduction

Vision is the most important part of the human perception system. Humans can visually identify various attributes of objects, such as their shape, size, color, motion, etc. These attributes constitute various important visual information of objects. It is a trend of science and technology to analyze and process the images collected by cameras, image capture cards and other devices and extract some important structural information. The characteristics of the human visual system make us pay more attention to the overall structure of the image when we perceive an image and ignore some details. Because of the diversity and complexity of the features, the difficulty of image understanding has increased, which brings certain difficulties to subsequent image processing and related operations of computer vision. Therefore, extracting effective structure information from images has extensive research and application value. It not only helps image understanding, but also can be applied to computer vision tasks such as target recognition and scene understanding.

In recent years, due to the increasingly high requirements of pattern recognition, edge and contour detection technology has become an important research topic as the basis of pattern recognition research. With regard to research in this area, new methods have emerged one after another. At the same time, researchers have become more aware of structure and edges, and related research has begun to slowly shift from edge detection to boundary and contour detection. The large neighborhood [1], multi-scale, multi-direction [2], and multi-feature [3] have been introduced into contour detection. In recent years, excellent edge and contour detection algorithms have been used to implement these features. In addition, with an increasing number of manually annotated databases, researchers have explored other methods such as machine learning algorithms and optimization solutions. The method of machine-based contour detection [4] and the global optimization of contour detection [5] have also been researched. Lejeune A et al. [6] proposed a locally adaptive detection algorithm based on probability decision rules. The algorithm illustrates the probabilistic characterization of the local neighborhood as a benefit of improving the application of distance images. The segmentation method proposed by Rital S et al. [7] is more accurate than the graph-based segmentation algorithm by using a normalized cutting criterion. Ren H et al. [8] proposed a new edge detection scheme based on single-pixel imaging in the frequency domain. Nandal A et al. [9] proposed image edge detection based on the characteristics of fractional calculus and contrast enhancement.

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Structure as a basic feature of an image contains a large amount of meaningful information in the image. Image structure extraction technology can not only greatly improve the quality of image comprehension, but also can be applied to computer vision fields such as target recognition, image segmentation, saliency analysis, and has extensive research and application value. In addition, the filtering techniques [10] that have emerged in recent years require the filtering of unnecessary details while maintaining the integrity of the image's significant structure, so the filtering effect largely depends on the quality of the structure extraction. This paper presents an image classification method based on the relationship between variable values of different color spaces of color images and their background features. Appropriate image filter operators are used for edge optimization for different background images. The algorithm can remove background edges and preserve the edge features of the target object.

2. Color Image Classification

In the process of taking a color image, due to the influence of various factors such as the light intensity, the environment and the weather conditions, the background image of the captured image varies. Common background types include dark backgrounds, normal backgrounds, bright backgrounds, and special background tones. As shown in Fig. 1, the backgrounds of the six color images are different, and the intensity of the edge features of the objects are also very different. Therefore, it is necessary to select suitable image processing methods based on different background image features.

(a) (b) (c) (d) (e) (f)

Figure 1. Colorful images of different backgrounds

Ideally, when the light is normal and the background of the image is simple, the target will be more prominent. Therefore, edge feature extraction can be performed by simply filtering the image. However, when the effects of other factors such as overexposure or insufficient illumination make the image features more blurred, it is necessary to perform contrast enhancement processing on the images. Its processing effect is often different due to the different background color distribution of the image. In this paper, according to the relationship between variable values and image features in image color space, the image is divided into the following categories according to background features: special color background image, foreground highlight image, background highlight image, and normal background image.

The pixel average of the RGB channels of the normal color background image is relatively close. According to statistics, when the absolute value of the difference between the RGB three-channel pixel average value of the image exceeds 20, the image characteristics of the transmission line show that a certain color covers a large area and the color is prominent. This situation will seriously affect the normal processing of the image. This article sets the threshold to 25. The algorithm stipulates that if one of the absolute values of the difference between the pixel values of the three channels of the image RGB exceeds the set threshold, the image is classified as a special color background image.

The value obtained by the maximum variance between classes is used as the segmentation threshold T_1 of the foreground background. When the value T_1 is smaller than the image gray average value, if the image gray average value is greater than 170 and the absolute value of the difference between the pixel gray value average and the desired foreground background splitting threshold is less than 40, the image is classified as a foreground highlight image. When the absolute value of the difference between the image RGB three-channel pixel averages is less than 8, the image is also classified as a foreground highlight image. If the image gray average is less than 120, and the absolute value of the difference between the gray average and the foreground background segmentation threshold is greater than 40, the image is classified as a background highlight image. Otherwise, the image is classified as a normal background image.

Therefore, from the six graphs in Figure 1, we can see: Figures 1 (a), (b) belong to the background highlights; Figure 1 (c) belongs to the foreground highlights; Figure 1 (d) belongs to a special color background; Figures 1 (e), (f) are normal background images.

3. Image Preprocessing

Because the image contains a lot of noise in the process of photographing and transmission, or because the environmental factors cause the details of the captured image to be insignificant, these bring great disturbance to the image feature extraction. The purpose of image preprocessing is to eliminate these effects as much as possible in preparation for the next step in image feature extraction and analysis. This image preprocessing step includes: image graying and filtering.

In the premise of keeping the details of the image as much as possible, image filtering removes the target image noise. This is an indispensable operation link in image preprocessing. The quality of its processing will affect the reliability of subsequent image processing analysis. This paper introduces the principle and characteristics of the four filtering methods of mean filter, Gaussian filter, median filter and bilateral filter, and analyzes the suitable filtering method according to the image characteristics of different background types.

3.1. The Principle and Characteristics of The Four Filtering Methods

3.1.1. Mean Filter

Mean filtering is a linear filter. The basic principle is to use a template to traverse the pixels one by one and use the average gray value of the template including all the pixels to replace the pixel gray value of the central pixel of the template. It is also known as the neighborhood average method. The mathematical expression is:

$$z(k,l) = \sum y(i,j)/n \tag{1}$$

Where: $(i,j) \in S$. S represents the template size; $y(i,j)$ represents the gray value of each pixel in the template; $z(k,l)$ represents the pixel gray value of the template center pixel; n is the number of pixels included in the template.

Mean filtering removes random noise and is fast. However, in the process of denoising, it is easy to destroy the details of the image and weaken the edge information, so the image becomes more blurred. As the size of the template increases, the blurring phenomenon becomes more serious.

3.1.2. Gaussian Filter

Gaussian filtering is also a linear filter. The basic principle is to use a template to traverse the pixels one by one. Each pixel in the template corresponds to a certain weighted value. The weighted average gray value of the pixels included in the template is used to replace the gray value of the central pixel of the template. Its mathematical expression is:

$$z(k,l) = \sum [a_{ij} \times y(i,j)]/n \tag{2}$$

Where: $(i,j) \in S$. S represents the template size; $y(i,j)$ represents the gray value of each pixel in the template; $z(k,l)$ represents the pixel gray value in the center of the module; n is the number of pixels included in the template; a_{ij} represents the weight value at the coordinate point (i,j). Since the change of the weight coefficient with distance is considered, the smoothing effect of the Gaussian filter is softer than the average filter, and the edge retention effect is better.

3.1.3. Median Filter

Median filtering is a non-linear filter. The basic principle is to use templates to traverse pixels one by one and replace the gray value of the pixels in the center of the template with the median of the gray values of all the pixels included in the template. The mathematical expression is:

$$z(k,l) = median\{y(i,j)\} \tag{3}$$

Where: $(i, j) \in S$. S represents the template size; $y(i, j)$ represents the gray value of each pixel in the template; $z(k,l)$ represents the pixel gray value in the center of the module. The median filter operation is relatively simple. The ability to remove isolated noise points is stronger than the average filter and bilateral filter. The ability to maintain the edge of the image is also strong, and there is a good balance between image denoising and boundary preservation.

3.1.4. Bilateral Filter

Bilateral filtering is also a kind of non-linear filtering, and its principle is similar to Gaussian filtering. However, bilateral filtering not only considers the influence of the distance between pixels on the weighting factor, but also considers that the more the difference in pixel gray values, the smaller the weighting factor. The mathematical expression is given by (4).

$$g(i, j) = \frac{\Sigma_{k,l}(f(k,l)w(i, j,k,l))}{\Sigma_{k,l}w(i, j,k,l)} \tag{4}$$

In the formula: $g(i, j)$ represents the gray value of the pixel in the center of the module. $f(k,l)$ represents the gray value of each pixel in the template, $(k,l) \in S$. S represents the size of the template. $w(i, j,k,l)$ represents the weight factor at the coordinate point (k,l) , and the formula is shown in formula (5).

$$w(i, j,k,l) = \exp\left(-\frac{(i-k)^2 + (j-l)^2}{2\sigma_d^2} - \frac{\|f(i, j) - f(k,l)\|^2}{2\sigma_d^2}\right) \tag{5}$$

Bilateral filtering considers both the spatial proximity and the similarity of pixel values of an image and preserves edges very well. In addition, bilateral filtering is effective for filtering low-frequency noise but not for high-frequency noise filtering.

3.2. The Selection of Filtering Method

On \ one hand, filtering eliminates the noise of the image itself, and on the other hand, it reduces the noise that may be generated by the contrast enhancement processing and provides reliable and effective protection for subsequent image processing and analysis. By analyzing the principle and characteristics of various filtering methods and performing multiple image processing experiments, this paper summarizes the filtering methods applicable to different background type images as follows. See the following table for details.

Table 1. Suitable filtering methods of different type images

Image type	Average gray value H	Filter operator
Special Color Background Image	$H \le 130$	Mean filter
	$H > 130$	Gaussian filter
Foreground Highlight Image	$0 \le H \le 255$	Median filter
Background Highlight Image	$0 \le H \le 255$	Gaussian filter
Normal Background Image	$0 \le H < 150$	Bilateral filter
	$150 \le H < 190$	Gaussian filter
	$190 \le H \le 255$	Median filter

As shown in Table 1, for a special color background image, when the light is not particularly weak, we specify that when the H value is greater than 130, the algorithm does not perform contrast enhancement processing and the Gaussian filtering method soothes the denoising. Conversely, when the H value is less than or equal to 130, the algorithm performs contrast enhancement processing and uses average filter processing.

For the prominent image in the foreground, since the features are more obvious and the conditions such as overexposure or edge blurring due to other factors do not frequently occur, the contrast enhancement processing is not performed and only a median filter is performed. For background highlighting class images, such images generally have large, dark backgrounds such as buildings or dark clouds. After the contrast enhancement process, the noise is obvious, and even the edge details are seriously damaged. It is also not suitable for the contrast enhancement process. Here, only one Gaussian filter is performed.

For normal background images, when the light intensity is strong, H is greater than or equal to 190, the contrast enhancement processing is performed, and the filtering is subjected to median filter processing. When the illumination is weak, H is less than 150, contrast enhancement processing is performed, and bilateral filter processing is adopted. When the light is normal, when H is between 150 and 190, no contrast enhancement processing is performed, and only Gaussian filtering is performed once.

4. Image Detection in Complex Background

In this paper, the edge features of various color spaces are extracted and optimized based on the canny operator edge detection, multiscale operators and morphological operations. First, after the image preprocessing is completed, the processed image is again subjected to the maximum class variance method, and the segmentation threshold T_2 of the foreground background is obtained. The data obtained by performing an appropriate arithmetic operation on T_2 will be used as a Canny edge detection parameter to detect edge features. Specific thresholds are shown in Table 2.

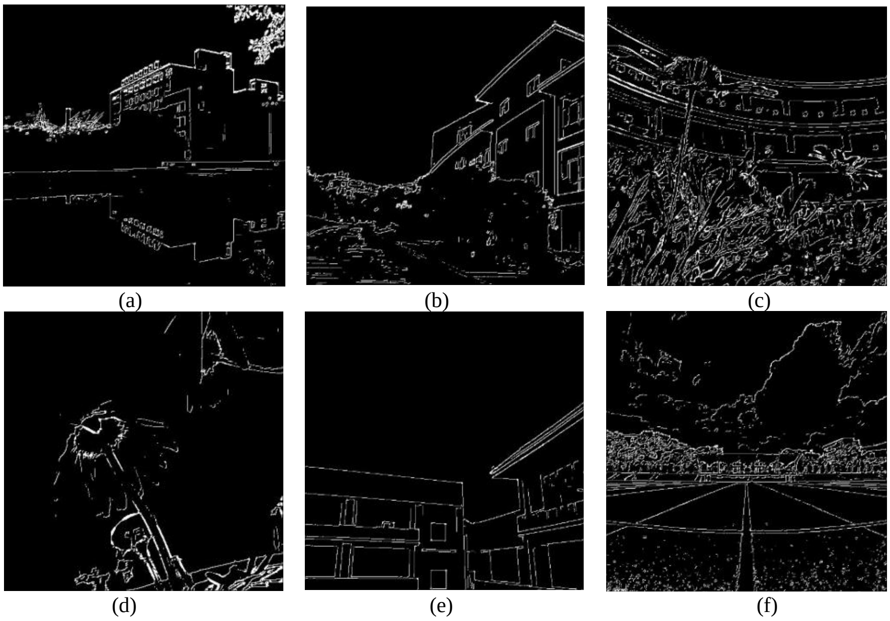
Table 2. Threshold of Canny edge detection

Segmentation threshold range of foreground background	Low threshold	High threshold
$T_2 \leq 100$	$thresh/2$	$thresh$
$T_2 > 100$	$(thresh \times 0.7)/2$	$thresh \times 0.7$

Then, the multi-scale analysis was performed on the Canny edge-detected image to complete the edge feature extraction of the image. The detailed steps are as follows:

- Step 1: Input a color image and grayscale it; calculate the average gray value H ;
- Step 2: Calculate the foreground segmentation threshold T_1 of the grayscale image by using the maximum variance between classes.
- Step 3: According to the classification rules, classify color images into special color backgrounds, foreground highlights, background highlights, and normal backgrounds;
- Step 4: According to the image classification, combined with the range of the average gray value H , for different types of color images, determine the filter operators used to achieve grayscale image preprocessing;
- Step 5: Calculate the foreground segmentation threshold T_2 again for the preprocessed image.
- Step 6: Perform an appropriate arithmetic operation on T_2 as an edge detection parameter to implement edge detection of the Canny operator.
- Step 7: Use the multi-scale theory, combined with morphological erosion dilation, to further correct the edges.

By establishing an algorithm, the following results are obtained:



(a) (b) (c) (d) (e) (f)

Figure 2. Image edge processed by threshold T_1

As seen from Figure 2, the image extraction effect is very good by using the preprocessing of color space variable classification. The contour extraction is complete and the details are better preserved. As seen from Figure 3, using this algorithm, the final image processing results are good, and its feature edges are well preserved. Figure 3 (b) highlights the image and the background is better. Figure 3(c) is an image of the foreground highlighting class. The outline of the daisies remains intact. Figure (d) is a special color background class. The color of the flower and the background sky are very close. The algorithm captures the stem of the flower more completely. For the normal background image, the edges of images (e) and (f) are very similar to the original image. The effect is ideal.

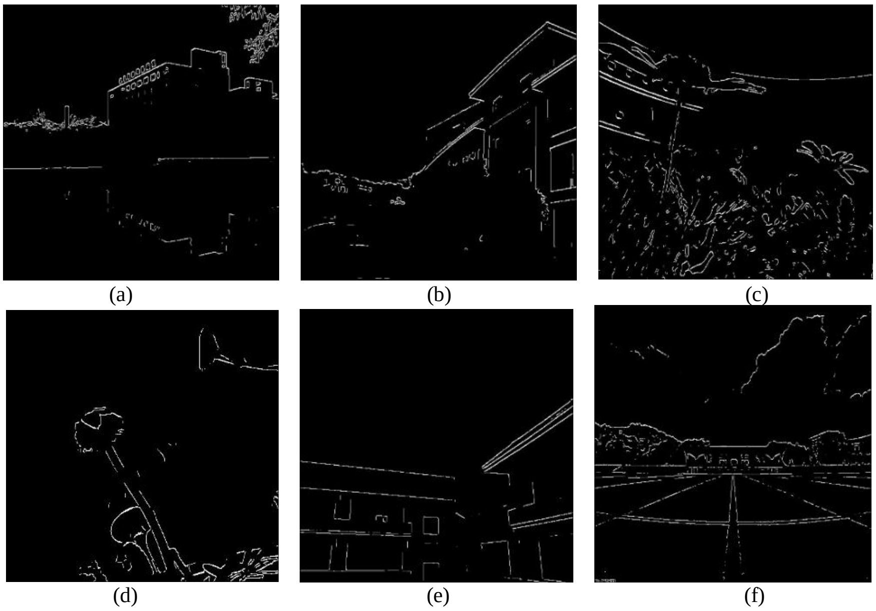


Figure 3. Images after final processing

5. **Conclusions**

This paper summarizes a multi-background image classification and edge feature extraction method by analyzing the relationship between the background features of color images and the values of different variables in each color space. The method specifically processes images of different background types and enhances the reliability of image processing. Choosing the right filtering method can better remove the image noise. The maximum difference between classes is used to obtain the threshold and is set as the Canny edge detection parameter, which can better extract the edge features of the image. After many experiments, the feasibility of the method was confirmed, and a new idea and method were provided for the intelligent processing of color images.

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