A Canny operator road edge detection method based on color features

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Abstract. The road edge detection method, proposed by us, highlights the morphological and color features of the road in the image. The method performs color space conversion and color feature screening on color images containing road information, and Canny operator is used for edge detection. Then the edge detection results are detected by straight lines, and the road edges are detected and marked based on the principle of Hough transform. The experiment of edge detection on road pictures with complex background proves that the detection method can better detect the road edge. The novelty of this method is to combine several principles such as color feature screening, Canny operator and Hough transform. Therefore, a new method of road edge detection is formed.

1. Introduction
With the COVID-19, society's expectations for unmanned inspections are becoming more and more urgent, so that road edge detection technology has become more and more important.

In image processing, the edge is the set of points where the gradient of the gray value of the pixels in the picture changes sharply in the detected object. Among various detection algorithms, common edge detection operators include Laplacian operator, Sobel operator, Roberts gradient [1]. In this paper, in order to improve the problem of insufficient utilization of color features in Hough lane line detection [2], in order to improve the problem of insufficient utilization of edge straight lines based on color difference Canny edge detection operator [3], a road edge based on color feature based Canny operator is proposed Detection method.

2. Traditional Canny operator based on Sobel gradient
The Canny edge detection operator [4] is an edge detection algorithm developed by John F. Canny in the 1980s. The traditional Canny edge detection principle based on Sobel gradient can be divided into three steps.

2.1. Gauss filter
The main function of Gauss filtering is to smooth and denoise the original image, so Gauss filtering is also called Gauss smoothing in Canny operator. The basic principle of Gauss filtering is to use a certain size of Gauss kernel to convolve with the target image to be processed, so as to achieve the purpose of denoising and blur smoothing.
2.2. Gradient calculation using Sobel operator

The Sobel gradient operator [5] is composed of two 3×3 matrices. The two matrices perform gradient calculations in the horizontal and vertical directions of the processing object, and the two operators and the image matrix can be calculated to obtain horizontal and vertical two. Directional gradient approximation matrix. After the two matrices are combined, the overall gradient approximation matrix of the image can be obtained.

2.3. Non-maximum suppression and threshold processing

The maximum value refers to the maximum value of the gradient value of the pixel in the positive and negative gradient directions. The purpose of non-maximum suppression is to remove the spurious effect of edge detection, so that the edges are more prominent and accurate. The role of threshold processing is to further highlight and strengthen the edges.

3. Improved Canny operator road edge detection

3.1. Overall improvement concept

In actual road information, the color features include very important road edge information such as the location of the road and the environment composition. When applying the traditional Canny operator for road edge detection, important information due to color features may be lost. Therefore, this paper proposes an improved Canny operator edge detection method based on color features. The flow chart is shown in Figure 1.

![Figure 1. The flow chart of the improved edge detection method.](image)

First, by changing the color space of RGB pictures from RGB to HSV, according to the color characteristics of the general road, color screening is performed, and the non-road part is removed by the color selection rate to filter out the road part.

Second, Gauss blur, image graying, gradient transformation and edge detection are performed on the color-filtered picture to complete the Canny operator calculation.

Thirdly, the straight edge characteristics of the road are used to perform road edge detection based on the principle of Hough transform on the picture after edge detection using the Canny operator, and the edge of the road part is determined through the usual road curvature range.

Finally, the detected road edge is marked to achieve the function of extracting road edge information.

Through improvement, the color picture containing road information can better detect the road edge after three steps of color space change and color screening, Canny operator edge detection, and road edge detection based on the principle of Hough transform.

3.2. Change of color space and color screening

The RGB color space can be understood as any color can be mixed by a certain ratio of three colors of red (R), green (G) and blue (B). Because the human eye cannot directly perceive the type of color through the mixing ratio of the three colors, the HSV color space is more intuitive to express colors than the RGB color space. The HSV color space can be understood as any color can be expressed by
the three parameters hue (H), saturation (S) and lightness (V). In this paper, the conversion method from RGB color space to HSV color space is:

\[
C_{\text{max}} = \max \left( \frac{R}{255}, \frac{G}{255}, \frac{B}{255} \right)
\]

\[
C_{\text{min}} = \min \left( \frac{R}{255}, \frac{G}{255}, \frac{B}{255} \right)
\]

\[
H = \begin{cases} 
0 & C_{\text{max}} = C_{\text{min}} = 0 \\
60 \times \left( \frac{G/255 - B/255}{C_{\text{max}} - C_{\text{min}}} \right) \mod 6 & C_{\text{max}} = R' \\
60 \times \left( \frac{B/255 - R/255}{C_{\text{max}} - C_{\text{min}}} + 2 \right) & C_{\text{max}} = G' \\
60 \times \left( \frac{R/255 - G/255}{C_{\text{max}} - C_{\text{min}}} + 4 \right) & C_{\text{max}} = B'
\end{cases}
\]

\[
S = \begin{cases} 
0 & C_{\text{max}} = 0 \\
\frac{C_{\text{max}} - C_{\text{min}}}{C_{\text{max}}} & C_{\text{max}} \neq 0
\end{cases}
\]

\[
V = C_{\text{max}}
\]

The HSV in Eq. 3, Eq. 4, Eq. 5 represents the H, S, and V components of the HSV model after the RGB color model conversion. After the color conversion, the model of the road picture in the HSV color space can be obtained. By comparing the obtained color HSV parameters with the corresponding real-world road colors in the HSV parameter range in the HSV color space, the HSV parameter is the required color in the range, and the HSV parameter is in the out of range. No color is required, and each pixel in the picture can be filtered to the road section in the picture that contains road information after reading the number and comparing the parameters.

3.3. Improved Gauss filtering

In the Canny operator Gauss filter based on color features, the Gauss filter that is different from the traditional Canny operator processes grayscale images, and the improved Gauss filter is a color image containing road information after Gauss kernel color processing in two dimensions. By processing the image, to blur out the small areas in the picture that are close to the road color accidentally, so as to remove the inaccurate edge detection caused by the close color.

Gauss filtering is performed on the pictures with road features that retain the color features, which can more effectively remove the useless information in the pictures, while retaining the useful color information. Therefore, after filtering, the road edge information in the color features can still be retained.

The Gauss kernel of Gauss filtering is composed of Gauss functions in x and y dimensions. In this paper, the Gauss functions of the two dimensions take the same standard deviation, and the basis for their determination [6] is:

\[
G(x, y) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{x^2 + y^2}{2\sigma^2}\right)
\]

3.4. Graying the color image of road information
The pictures containing road information have been filtered by Gauss, and the interference caused by small pixel impurities has been removed. The next step is to perform gradient calculation and edge detection on the processed image. But before the gradient calculation, the Gauss filtered image needs to be grayed. Common methods of image graying include component method, maximum value method, average value method and weighted average method.

In the grayscale of color images, the weighted average method used in this paper is to assign weights to the three colors according to the importance of the three colors of red, green and blue, and assign them to the grayscale image according to the different weights. Use the corresponding color. Calculation formula:

\[ \text{Gray} = 0.2989 \times R + 0.5870 \times G + 0.1140 \times B \]  

(7)

Gray represents the result of the image after gradation, and R, G, and B represent the RGB parameter values of the color image.

3.5. Sobel operator gradient calculation for grayscale images

A is the grayscale image matrix to be gradient operation, The calculation method is as Eq. 8, Eq. 9.

\[ G_X = S_X \ast A = \begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \ast A \]  

(8)

\[ G_Y = S_Y \ast A = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{bmatrix} \ast A \]  

(9)

3.6. Non-maximum suppression and threshold processing

Non-maximum suppression is to remove the stray effect of edge detection by selecting the maximum point of the gradient value of the pixel in the positive and negative gradient direction as the edge point and discarding the non-maximum point.

The threshold processing method is to set the upper and lower thresholds of edge pixels. When the gradient value is higher than the upper threshold, the edge is strengthened. When the gradient value is lower than the lower threshold, it is not used as a road edge. In this way, it can further highlight the actual edge of the road.

3.7. Road edge detection and marking

Hough detection [7] is a detection method based on image features. The basic principle of Hough line detection [8] is to detect the straight line through the statistical characteristics of the point of the parameter space through the one-to-one correspondence between the image space and the parameter space. The basic idea of road edge detection is shown in Figure 2.

![Figure 2. The basic principle diagram of road edge detection.](image)
Each point has a coordinate in the plane rectangular coordinate system x-y space, such as point A and point B. Points A and B in x-y space can form a straight line. If the coordinates of points A and B are transformed into k-b parameter space, it can be found that points A and B in k-b space intersect at a point, it is also concluded that when two points forming a straight line in x-y space correspond to k-b space, they intersect with one point. This is the principle of duality. In the straight line detection process, the point in the k-b space corresponding to the pixel that has the most intersection lines is the straight line we want to detect.

This method uses the straight line features of the general road edge to obtain the road edge image after detecting the edge detection. For each pixel point in the x-y image space or r-θ image space corresponds to the parameter space, using statistical principles find the road edge from various edges.

Based on the road edge detection based on the principle of Hough transform, the trigonometric function relationship can be used to obtain two sets of coordinate points that determine the corresponding straight lines on both sides of the road. Due to the perspective principle, the distance between the two sides of the road with little change in actual width is closer to the distance from the detection point in the image. It is also because objects that require road edge detection, such as self-driving cars, are generally located on the road. Therefore, the edge of the road detected in the picture can be determined and marked.

4. Experimental verification
In order to verify the effectiveness of the Canny operator road edge detection algorithm based on color features, this paper selects a picture containing a road with a complex background for road edge detection, as shown in Figure 3.

![Figure 3. The original road picture to be detected.](image1)

![Figure 4. Road picture after color filtering.](image2)

Firstly, the image is converted from RGB color space to HSV color space. After the conversion is completed, color filtering is performed. The pixels that meet the range conditions are set to white, and the pixels that do not meet the setting are black. The filtered binary image is Figure 4. After synthesizing the original picture and the binary picture obtained after filtering, a color picture with a composite color range, such as Figure 5 is obtained.

![Figure 5. Color road picture after color filtering.](image3)

![Figure 6. Gauss filtered road picture.](image4)
After the color screening and synthesis are completed, the $7 \times 3$ Gaussian kernel is used to Gauss filter such as Figure 6. After Gauss filtering is completed, binarize the image with threshold, such as Figure 7.

After the edge detection of the Canny operator is completed, the step radius of the straight line search with 1 pixel as the distance accuracy is used, and the threshold of the accumulation plane is 100, the road edge detection based on the principle of Hough transform is performed, and the original image is marked. The detected road edge is like Figure 8.

**Figure 7.** Road picture after edge detection.  **Figure 8.** Road edge detection and marking picture.

5. Conclusions
Experiments verify the road edge detection method of Canny operator based on color features proposed in this paper, which combines color screening of HSV color space with Canny operator edge detection method, and combines Hough detection method with Canny operator edge detection method. Through the application of edge detection methods in pictures containing road edge information, the color features containing road information can be more fully utilized, and the road edges in the pictures can be determined more effectively. However, this method has certain requirements for the color and shape of the road.

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