International Core Journal of Engineering Volume 7 Issue 6, 2021
ISSN: 2414-1895 DOI: 10.6919/ICJE.202106_7(6).0002

Edge Detection based on Gray Correlation

Xiyu Liang
College of Instrumentation & Electrical Engineering, Jilin University, Changchun 13000, China.
liangxy18@mail.jlu.edu.cn

Abstract

In the edge detection algorithm, being able to accurately detect the edge of the target object is the premise of extracting the target object. For the scratch detection of high-speed train axles, accurate edge detection can improve the basis for subsequent 3D reconstruction and size measurement of scratches. In this paper, an edge detection template based on gray correlation is designed for the axles of high-speed trains, which can accurately locate the edges of scratches; for scratches at different angles, filters in different directions are added. By comparing the filtering results of different rotation angles, the angle with the best result is selected as the rotation angle of the pixel. This method not only has excellent edge positioning performance, but also can eliminate most of the noise in the image and improve the effect of edge extraction.

Keywords

Edge Detection; Gray Correlation; Roberts Operator; Prewitt Operator.

1. Introduction

In the 21st century, with the rapid development of science and technology in our country, motor vehicle travel has gradually entered the public's field of vision [1]. For high-speed trains, the axle is an extremely critical component. When running at high speeds, turning or accelerating, the axles are subject to great stress. If the axle surface scratches, as scratches meet certain criteria may be broken in cornering, acceleration process, the threat to the safety of passengers. Therefore, it is necessary to detect the scratches on the surface of the axle, and the potential risks can be discovered in time to ensure the safety of passengers to the greatest extent. At present, the inspection of most axles requires human eyes to complete. This method is more dependent on the experience of the worker, the degree of detail of the observation, and the state of the inspection, and the error is relatively large [2]. Therefore, it is necessary to use image processing technology to detect the scratches in the image, and extract the outline of the scratches from the image.

The most commonly used method of edge detection is to detect based on the gray level mutation. The purpose of edge detection is to identify the point where the gray value of the digital image has a step change, and it can detect the place where the gray level changes drastically in the image, that is, the target The place where the object appears [3]. Unnecessary parts can be eliminated through edge extraction, and the parts to be detected in the image are retained. The principle of edge detection is to convolve an image by using different edge detection operators, commonly used edge detection operators include Roberts operator, Prewitt operator, Sobel operator, Laplacian operator and Canny operator [4]. Roberts operator, Prewitt operator, Sobel operator are not very accurate for the positioning of the edge of the object to be measured, and the detection result of Laplacian operator will form discontinuous edges. Although the Canny operator can detect the real edge, because the Canny operator uses a one-dimensional Gaussian filter to convolve the original image [5], and the parameter σ needs to be set manually, it has a poor filtering effect on salt and pepper noise. In addition, the traditional Canny algorithm determines the edge of the image by artificially setting high

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and low thresholds, which may cause inaccurate detection [6]. This paper proposes a method to detect edges through the correlation of filtered gray histograms, which can effectively avoid false edges and missed detection.

2. Traditional edge detection algorithm

2.1 Roberts algorithm

Roberts operator [7] is one of the simplest edge detection operators. It is a 2×2 filter template composed of two convolution kernels in the x direction and y direction. As shown in formula (1)

$$R_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, R_y = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix} \tag{1}$$

Among them, R_y is obtained by rotating R_x clockwise 90°. Through this convolution kernel filtering, the gradient components in two directions can be obtained, G_x and G_y respectively

$$\begin{aligned} G_x &= 1 \times f(x,y) + 0 \times f(x+1,y) + 0 \times f(x,y+1) + (-1) \times f(x+1,y+1) \\ &= f(x,y) - f(x+1,y+1) \end{aligned} \tag{2}$$

$$\begin{aligned} G_y &= 0 \times f(x,y) + 1 \times f(x+1,y) + (-1) \times f(x,y+1) + 0 \times f(x+1,y+1) \\ &= f(x+1,y) - f(x,y+1) \end{aligned} \tag{3}$$

The formula for calculating the magnitude of the gradient is

$$|G| = \sqrt{{G_x}^2 + {G_y}^2} \tag{4}$$

The angle calculation formula of the gradient is

$$\theta = \arctan(\frac{G_x}{G_y}) \tag{5}$$

The advantage of Roberts operator is that the calculation speed is fast, but the positioning accuracy is not high [8]. But because of its template characteristics, Roberts operator can detect the edge that is 45° or 135° with the horizontal line. Because the Roberts operator uses a 2×2 filter template, it is a local difference algorithm, which is more sensitive to noise and usually produces a relatively wide response near the edge of the image.

2.2 Prewitt algorithm

The Prewitt operator [9] is a first-order differential operator, which mainly uses the gray level difference between the left and right neighborhoods of the center pixel and the gray level difference between the upper and lower neighborhoods to detect edges. The Prewitt operator is a 3×3 template, which is also composed of templates in two directions.

$$P_x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}, P_y = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \tag{6}$$

Among them, P_x and P_y are two mutually perpendicular templates. The gradient difference G_x of the image in the horizontal direction can be obtained by convolving the image with P_x, and the gradient difference G_y of the image in the vertical direction can be obtained by convolving the image with P_y. Because it is necessary to manually set the threshold when judging whether it is at the edge, there will be a certain error in the detection. If the threshold is selected too large, it may be missed; if the threshold is too small, the noise in the image may be judged to be displayed as an edge.

3. Edge detection algorithm based on gray correlation

In order to solve the problems of the above-mentioned traditional edge detection operators, such as inaccurate edge positioning, missed detection, and misjudgment, this paper designs a filter template, as shown in the figure

ISSN: 2414-1895 DOI: 10.6919/ICJE.202106_7(6).0002

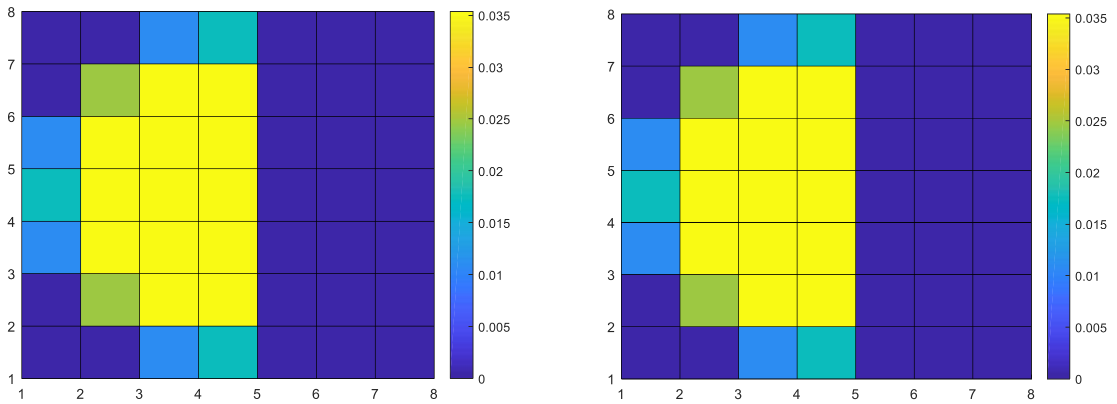

Figure 1. Filter template

Traditional edge detection operators, such as Roberts operator, Prewitt operator, use square filters, there is a problem with this kind of filter, that is, the pixels on the diagonal of the square filter are the farthest from the center pixel, and the impact on the center pixel is also the smallest, when the filter reaches a certain size, the pixels that are far away may not be on the same plane as the center pixel. In order to solve this problem, this paper designs a circular filter template as shown in the figure. Different colors in the template represent different weights. When the image is enlarged to a certain multiple, it will be observed that the pixels are not standard squares, so some pixels cannot be included in the template when filtering. For some weights that can all be included in the filter are set to the same, the pixels representing these positions have the same influence on the center pixel. For the pixels on the boundary of the circular filter template, different weights are set according to the ratio of the area contained in the template to the area outside the template.

Figure.1 shows a 7×7 template as an example. Mark the filter on the left in Figure.1 as L_p and the filter on the right as R_p, and use these two filters to filter the input image f. The filtering result of L_p is denoted as F_{L_p}, the filtering result of R_p is denoted as F_{R_p}, and the filtering result is

$$F_{L_p}(\mathrm{x,y}) = \sum_{i=-3}^{3}\sum_{j=-3}^{3} L_p(i,j) f(x+i, y+j) \tag{7}$$

$$F_{R_p}(\mathrm{x,y}) = \sum_{i=-3}^{3}\sum_{j=-3}^{3} R_p(i,j) f(x+i, y+j) \tag{8}$$

After the filtering result is obtained, the histogram statistics should be performed on the image, and the statistical results are recorded as H_{L_p} and H_{R_p}. The correlation calculation is done on the statistical results of the histogram, and the calculation result is

$$\mathcal{L}\left(H_{L_p}, H_{R_p}\right) = \frac{\sum_{i=1}^{N} H_{Lp}(i) \cdot H_{Rp}(i)}{\sqrt{\sum_{i=1}^{N} H_{Lp}(i) \cdot H_{Lp}(i)} \cdot \sqrt{\sum_{i=1}^{N} H_R(i) \cdot H_{Rp}(i)}} \tag{9}$$

In formula (3.2), $\mathcal{L}\left(H_{L_p}, H_{R_p}\right)$ represents the correlation result of histogram statistics on the left and right sides, $H_{L_p}(i)$ represents the value of the i-th element in the histogram H_{L_p}, N represents the type of color after image quantization.

Because the scratches are not all in the same direction in the image, the filter in one direction cannot well retain all the scratch information. The filter designed in this paper can be rotated at a certain angle, by comparing the filtering results of different angle filters, the angle with the least correlation is the optimal angle of the pixel.

$$A_p = arg_{\theta_p} \min\left(\mathcal{L}\left(H_{\varphi(L_p)}, H_{\varphi(R_p)}\right)\right) \tag{10}$$

In formula (3.4), θ_p represents the angle of filter rotation at pixel p, and $H_{\varphi(L_p)}$ represents the histogram statistics result of filter L_p rotated by a certain angle θ.

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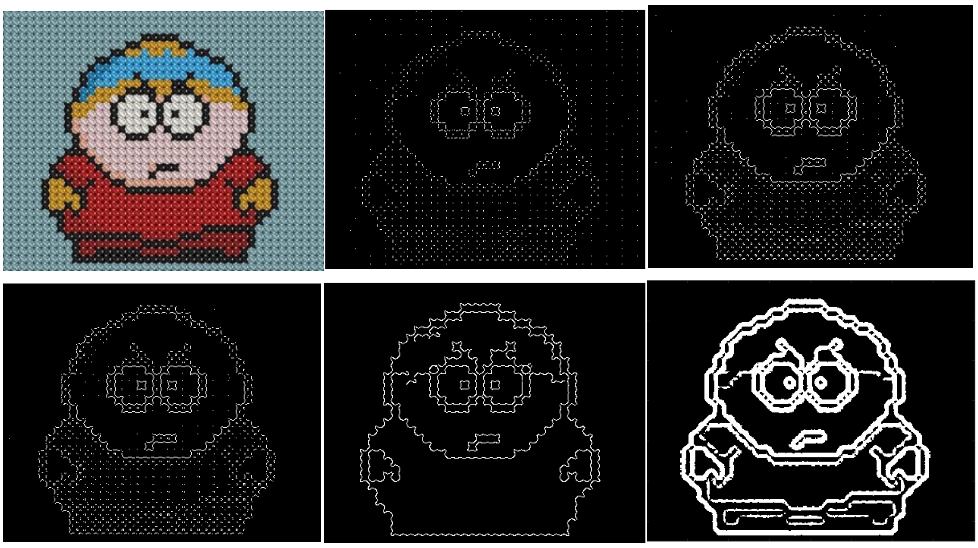

Figure 2. Comparison of detection results of several algorithms (a) Original image (b) Roberts algorithm test result (c) Sobel algorithm test result (d) Prewitt algorithm test result (e) Canny algorithm test result (f) The algorithm test result of this article

It can be seen that for the image in Figure .2, the Roberts operator has a large error in the edge detection, and both the Sobel operator and the Prewitt operator will miss the detection, the canny operator does not detect many internal edges in the image. The algorithm in this paper is very accurate in positioning the edge part of the image, and the noise is also well filtered.

When using this kind of filter to filter the image, because the pixel weight values at different positions in the filter are different, the radius of the filter will have a certain impact on the filtering result, as shown in Figure 3.

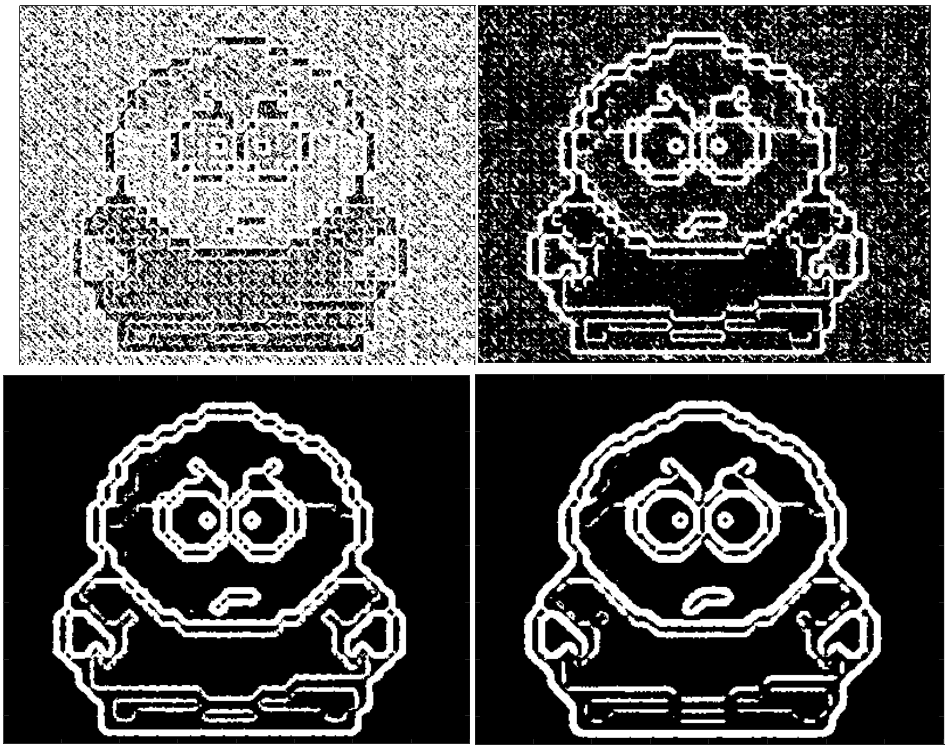

Figure 3. Comparison of edge detection effects of filters with different radius (The binarization threshold is 0.32) (a) A filter with a radius of 3 (b) A filter with a radius of 5 (c) A filter with a radius of 7 (d) A filter with a radius of 9

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It can be seen that the smaller the radius of the filter, the worse the filtering effect of the image, the irrelevant information in the image is all retained, and the larger the radius, after exceeding a certain threshold, the effect of retaining the edge information of the image is poor. For example, compared with a filter with a radius of 7 and a filter with a radius of 9, although there is noise in the image, the edge location of the image is more accurate, the filter with a radius of 9 reduces the noise in the image, but there are many internal edges in the image that are not detected, and there are burrs on the outside edges.

When performing edge detection on an RGB image, it needs to be binarized, and the threshold T selected during binarization is different, which will also affect the final edge detection effect. When the radius of the selected filter template is 7, the influence of different thresholds on the result is shown in Figure 4.

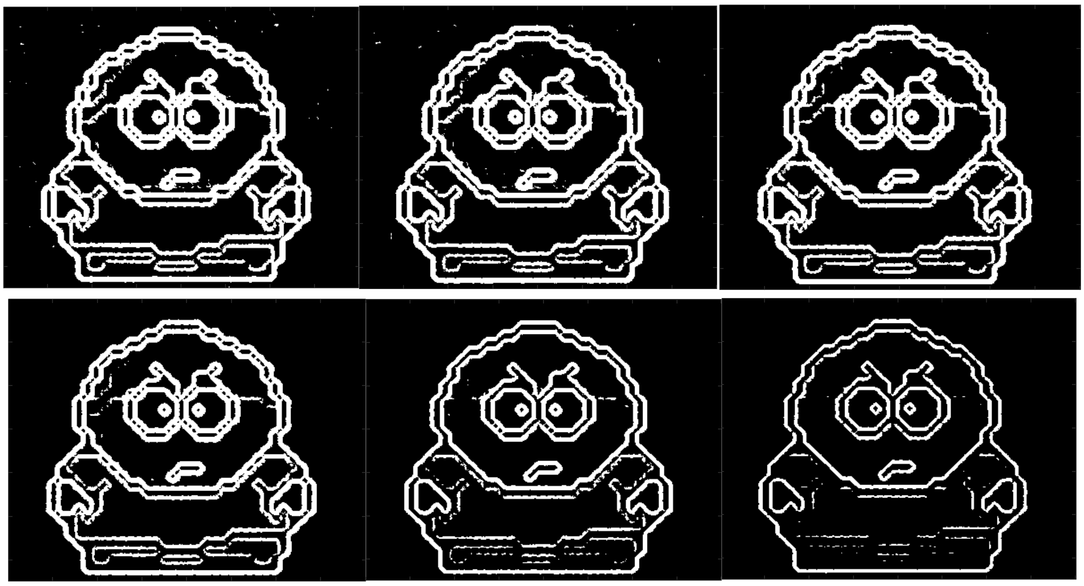

Figure 4. Comparison of the influence of different thresholds T on the filtering effect when the filter template radius is 7. (a) T = 0.26 (b)T = 0.28 (c)T = 0.3 (d)T = 0.32 (e)T = 0.4 (f)T = 0.5

Looking at Figure 4, we can see that as the threshold T increases, the better the effect of the filter, the less noise in the image. However, when the threshold T is increased to a certain extent, it will affect the judgment of the edge, resulting in the discontinuity of the edge.

4. Summary

In this paper, a filter template is designed for the edge detection of the scratches of the axle, and the gray correlation of the target pixel is used to determine whether the target pixel is on the edge curve, and the rotation of the filter template is used to adapt to the edges of different angles. Through the comparison between the algorithm in this paper and the traditional algorithm, the algorithm in this paper is superior to the traditional algorithm in terms of noise filtering and edge location. Traditional algorithms will have obvious missed detections and false edges. After selecting appropriate parameters, the algorithm in this paper can effectively preserve the edges of the image, filter out the noise in the image, and reduce the error rate of the detection results.

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