International Journal of Applied Mathematics in Control Engineering 5 (2022) 79-87

Contents lists available at YXpublications

International Journal of Applied Mathematics in Control Engineering

Journal homepage: http://www.ijamce.com

Workpiece Image Edge Detection Operator Based on Improved Sobel

Jingwei Guo, Jian Liu, Yang Zhou

School of Electrical and Control Engineering, Shenyang Jianzhu University, Shenyang, LN110000，CHINA

ARTICLE INFO

Article history:
Received 2 March 2022
Accepted 3 May 2022
Available online 5 May 2022

Keywords:
Sobel
image processing
object recognition
edge detection
noise immunity

ABSTRACT

Edge detection methods reduce the amount of actual operation without compromising the edge quality of the image under test. In order to solve the problems of poor continuity, low real-time and poor noise reduction ability when common edge detection algorithms detect image edges. An improved eight-way Sobel operator is proposed, and the traditional Sobel operator, Robert operator, Prewitt operator, Log operator and Cannny operator perform edge detection on the original small workpiece image and the small workpiece image after adding Gaussian noise and filtering respectively (where the variance of Gaussian noise is 0.02 and the mean is 0). Simulation experiments on MATLAB platform show that the improved Sobel operator has the characteristics of stronger continuity and better noise reduction ability, which greatly improves the edge detection effect and enhances the detection and identification efficiency of the target workpiece.

1. Introduction

Classical edge detection operators rely on differential first- and second-order operators[1], mainly prewitt, Sobel, Robert, Log, Canny and other operators. However, classical algorithms generally have shortcomings such as poor ability to digest noise, inability to extract graphical edges completely, and manual threshold setting. Cai Xinyue, Zhou Yang and others in China proposed a small object detection algorithm with super-resolution sharpening enhancement [2]. While increasing the image resolution, the algorithm effectively enhances the sharpness of the edges of the image, and can also better retain the details of the image, and offset the loss of detail by deep convolution to a certain extent. However, because the image fragmentation weakens the image characteristics of large targets, the detection speed of the algorithm is low. Guo Shuwei et al. used a sensor network to conduct boundary detection of polluted areas[3], which not only improved the detection efficiency and accuracy compared with manual handheld devices to detect concentrations, but also significantly expanded the monitoring range. However, the fixed monitoring sites are few, the liquidity is poor, and the distribution is uneven, making it impossible to directly monitor the concentration of the relevant area in an all-round way.

A foreign Alexander Seaman et al. proposed a target detection method based on the yolo v3 object detection model[4], which improves the detection accuracy and speed to a certain extent, but compared with the latest yolo v4 and yolo v5 detection methods, the performance is insufficient and the cost is also relatively high.

Aiming at the shortcomings of the current target workpiece edge detection method, in order to quickly and accurately detect the edge of the target workpiece and provide a reliable and high-precision identification image for the status detection of the target workpiece, this paper uses five differential operators of Prewitt, Sobel, Robert, Log, and Canny to carry out the edge detection of the original diagram and the noise image respectively, and analyzes the advantages and disadvantages and differences of each edge detection method, and proposes the target workpiece image edge detection based on the improved Sobel.

2. Several edge detection operators

Image edge detection [5] refers to the process of detecting points and line segments from the edges of an image and then outlining the direction of the edges. Edges appear when the image information changes, and since outlining the edges of the image requires the edge points with the same relationship to be connected into edge lines, the following formula is used to find the edge position and determine the edge orientation. With (x, y) to represent the position of the current pixel, f(x,y) for the store gray value, through differential calculation to obtain the gradient change of the gray image, because the gray image is a discrete two-dimensional function, differential calculation of the horizontal x and vertical direction y to obtain the gradient

* Corresponding author.
E-mail addresses: 2727092345@qq.com (J. Guo)

change, the calculation formula is as follows:

$$\frac{\partial f}{\partial x}=\frac{f(x+1,y)-f(x,y)}{\Delta x} \tag{1}$$

$$\frac{\partial f}{\partial y}=\frac{f(x,y+1)-f(x,y)}{\Delta y} \tag{2}$$

The minimum change of image pixels is 1, and , $\angle$ is used to represent the fastest direction of change in the gray value of the image, representing the gradient of the edge detection operator, and taking the inverse / can make the tangent function get the gradient direction, the formula is as follows:

$$\angle\nabla f(x,y)=\arctan\left(\frac{\partial f}{\partial y}\right)\Big/\left(\frac{\partial f}{\partial x}\right) \tag{3}$$

The amplitude of the gradient is used to indicate, that is, the magnitude of the gradient change, as follows:

$$\left|\nabla f(x,y)\right|=\sqrt{\left(\frac{\partial f}{\partial x}\right)^2+\left(\frac{\partial f}{\partial y}\right)^2} \tag{4}$$

The gradient amplitude is expressed in M, simplified (2).

$$M(x,y)\left|\frac{\partial f}{\partial x}\right|\left|\frac{\partial f}{\partial y}\right| \tag{5}$$

For any pixel point (x, y) in the image to be detected, you can determine whether the point is an edge point by setting a threshold [6], if the edge detection operator calculates the pixel gradient change amplitude exceeds the threshold, that is, the edge, you can get an image containing edge information, retain the most important information features in the image to be detected, eliminate other unrelated information and greatly reduce the amount of data in the image.

According to machine vision theory, the human eye to identify the object first to get the outline, and the computer vision system therefore imitates human vision to identify the target image, first of all to obtain the element diagram 1 characterizing the outline of the target image. Edge detection is the process of obtaining the contour of the target, which is an important foundation for machine vision, image analysis and acquisition of target features. It generally includes smooth filtering, edge detection, threshold segmentation, edge positioning, edge connection and other steps, as shown in Figure 1, wherein the first three steps are commonly used edge detection algorithms.

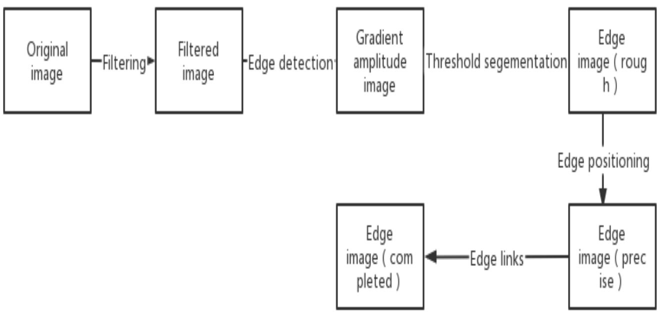


Fig. 1. Edge extraction flowchart

The Prewitt operator is a differential operator for image edge detection, the principle of which is to use the difference generated by the gray value of pixels in a specific area to achieve edge detection. Since the Prewitt operator uses a 3x3 template to calculate the pixel values in the region, and the Robert operator has a template of 2x2, the edge detection results of the Prewitt operator are more obvious in both the horizontal and vertical directions than the Robert operator. The Prewitt operator is suitable for identifying noisy, grayscale gradient images, and its calculation formula is as follows:

$$d_x=\begin{bmatrix}-1&0&1\\-1&0&1\\-1&0&1\end{bmatrix}\qquad d_y=\begin{bmatrix}-1&-1&-1\\0&0&0\\1&1&1\end{bmatrix} \tag{6}$$

The following is a template for the Prewitt operator, where the gradient size in the x and y directions at pixel P5 is calculated as g_x and g_y, respectively:

P1	P2	P3
P4	P5	P6
P7	P8	P9

-1	0	1
-1	0	1
-1	0	1

-1	-1	-1
0	0	0
1	1	1

Fig.2. Prewitt operator template

The formula is as follows:

$$g_x=\frac{\partial f}{\partial x}=(P7+P8+P9)-(P1+P2+P3) \tag{7}$$

$$g_y=\frac{\partial f}{\partial y}=(P3+P6+P9)-(P1+P4+P7) \tag{8}$$

The traditional Sobel operator is technically a discrete difference operator that is used to approximate the grayscale of an image luminance function.Using this operator at any point in the image will result in a corresponding grayscale vector or its normal vector.

The traditional Sobel convolution factor is shown in Figure 3:

-1	0	1
-2	0	2
-1	0	1

-1	2	1
-1	0	0
-1	-2	-1

Fig.3. Sobel operator convolution factor

The operator contains two sets of 3x3 matrices, horizontal and longitudinal, which are convoluted with the image in a plane to obtain approximate brightness differences in landscape and longitudinal orientations, respectively. If A is used for the original image, Gx and Gy represent the grayscale values of the image detected by the horizontal and vertical edges, respectively, the formula is as follows:

$$G_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \times A$$
$$G_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \times A \tag{9}$$

The Roberts operator is the simplest operator that uses a local difference operator to find the edge. The edge is detected using an approximate gradient amplitude of two pixels adjacent to the diagonal. The effect of detecting vertical edges is better than that of oblique edges, the positioning accuracy is high, and it is more sensitive to noise and cannot suppress the influence of noise. The Roberts edge operator is a 2x2 template that uses the difference of two pixels diagonally adjacent. From the actual effect of image processing, the edge positioning is more accurate and sensitive to noise.

The template for the Roberts operator is as follows:

$$G_x = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$$
$$G_y = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix} \tag{10}$$

For the input image $f(x,y)$, the target image output after using the Roberts operator is $g(x,y)$.

$$g(x,y) = \sqrt{\begin{aligned}&\left(f(x,y) - f(x+1,y+1)\right)^2 \\ &+ \left(f(x+1,y) - f(x,y+1)\right)^2\end{aligned}} \tag{11}$$

The LoG operator is an improvement on the Laplace operator. The Laplace operator is a simple second-order derivative operator, a scalar with linear, displacement invariance, whose messenger has a origin of 0 in the frequency domain space. All images filtered by the Laplace operator have zero mean grayscale. However, the disadvantage of this operator is that it has an unacceptable sensitivity to noise, so in practical applications, it is generally necessary to smoothly filter the image first, and then use the Lattice operator to detect the edge of the image. This is the background of the loG operator (the final gradient expression is the Gaussian function and the convolution of the original image, followed by the second-order differential operator).

Therefore, when designing a convolution template, the symmetry of the function should be designed to approximate the convolution effect of the function. Here the convolutional template takes the 5th order, as follows:

0	0	-1	0	0
0	-1	-2	-1	0
-1	-2	16	-2	-1
0	-1	-2	-1	0
0	0	-1	0	0

Fig.4. Log operator convolutional model

The Canny operator is a first derivative of the Gaussian function, the optimal approximation operator for the product of the signal-to-noise ratio and positional accuracy, consisting of the following four steps:

Step 1: Gaussian filtering of the image

The main role of Gaussian filtering is to smooth the image, reduce noise, and increase the width of the edges. The Gaussian function is similar to a normal distribution, and the gray value at (x,y) obtained after Gaussian filtering is C(x,y), and the gaussian filtered grayscale value can be obtained by the following formula:

$$C(x,y) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(\frac{\left(x^2+y^2\right)}{2\sigma^2}\right) \tag{12}$$

Step 2: Calculate the gradient amplitude and direction

In the image, gradients are used to indicate the direction and degree of change of the grayscale values, calculated as shown in the formula.

Step 3: Non-maximum suppression of amplitudes

Non-maximal suppression is used to filter points that are not edges, to make the edge width as few pixels as possible, to preserve the points with the largest gradient amplitudes in each direction, and to set the remaining pixel grayscale values to 0.

Step 4: Double threshold detection and connection edge

Select two thresholds of different sizes, divide the gray value of the pixel point into three categories, namely pixels that are greater than the high threshold and below the low threshold between the high and low thresholds, set the first type of pixel as a strong edge point, set the gray value to 1, determine the pixel below the low threshold as a non-edge point, set the gray value to 0, set the pixel between the high threshold and the low threshold as a weak edge point, and the weak edge can be determined as an edge when it is connected to a strong edge, thereby reducing the edge width and ensuring the continuity of edge detection.

3. Improved Sobel detection operator

Most of the edges of the picture is very complex, the edge direction is obliquely dominant, horizontal and vertical edges tend to be less, the traditional Sobel operator is not very accurate on the edge positioning, resulting in unsatisfactory effects, the edge of the image is far more than one pixel, the accuracy requirements are often unable to meet, so the use of improved octoper-based Sobel operator for detection, consider adding 22.5°, 45°, 67.5°, 112.5°, 135°and 157.5°six directions of convolution factor As shown in the figure, the image to be processed is convoluted with these 8 templates, each template has the greatest impact on the corresponding direction, the center of the edge detection operator corresponds to the pixel to be detected, and eight convolution operations are performed, and the maximum value of the result is the output bit of the point, and the operation result is an edge amplitude image.

$$\begin{array}{cccc}
\begin{pmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{pmatrix} &
\begin{pmatrix} -2 & -1 & 0 \\ -1 & 0 & +1 \\ 0 & +1 & +2 \end{pmatrix} &
\begin{pmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{pmatrix} &
\begin{pmatrix} 0 & +1 & +2 \\ -1 & 0 & +1 \\ -2 & -1 & 0 \end{pmatrix} \\
\rightarrow & \nearrow & \uparrow & \nwarrow \\
\begin{pmatrix} 0 & +1 & +2 \\ -1 & 0 & +1 \\ -2 & -1 & 0 \end{pmatrix} &
\begin{pmatrix} 0 & +1 & +2 \\ -1 & 0 & +1 \\ -2 & -1 & 0 \end{pmatrix} &
\begin{pmatrix} +1 & 0 & -1 \\ +2 & 0 & -2 \\ +1 & 0 & -1 \end{pmatrix} &
\begin{pmatrix} 0 & -1 & -2 \\ +1 & 0 & -1 \\ +2 & +1 & 0 \end{pmatrix} \\
\leftarrow & \swarrow & \downarrow & \searrow
\end{array}$$

Fig.5. Improved Sobel operator convolution model

The improved Sobel operator has been increased from the 2 directional templates of horizontal and vertical horizontal and vertical to 8 directional templates contained in the traditional Sobel operator to obtain more complete edge information. However, as with the traditional Sobel operator, for some edge detection information with noise images added, the improved Sobel operator edge detection effect is still poor, that is, the noise immunity is still poor. In summary, this article is improved by setting thresholds. The edge value detected by the Sobel edge detection operator is compared with the set threshold T, if the amplitude is greater than the threshold T, the point is defined as the edge, and if the amplitude is less than the threshold T, it is 0, that is, the point function g(j,k) is:

$$g(j,k)=\begin{cases} A\left|f_i(j,k)\right|\geq T \\ 0\left|f_i(j,k)\right|\leq T \end{cases} \tag{13}$$

In the equation: A is the edge point pixel value, 0<A≤255; is the result of the edge detection output.

Small workpieces on industrial production lines are susceptible to interference from light, masking, adhesion and other factors when collecting. Therefore, the selection of threshold T is particularly critical in edge detection of small workpieces. If the threshold is relatively low, more noise points will be retained and the edge detection effect will be reduced; If you choose a higher threshold, some edges with lower grayscale values are lost, resulting in the edges of the image not being fully displayed. For small workpiece images, after the edge detection is performed by using the improved 8-direction Sobel operator, the best threshold segmentation process is performed on the edge detection image by using the method of maximum posterior probability estimation to enhance its noise resistance. Zl(m,n) is used to represent the image after detection by the Sobel operator, hypothetic

$$z_1(m,n)=x_1(m,n)+y_1(m,n) \tag{14}$$

Wherein: the edge part of the original image of the small workpiece; It is Gaussian white noise with a mean of 0 and a variance of 0. The detected edge image is a high-frequency component that obeys the Laplace distribution, and its probability density function p(a) is

$$p(a)=\frac{1}{\sqrt{2}\sigma_x}\exp\left(-\frac{\sqrt{2}}{\sigma_x}|a|\right) \tag{15}$$

Where: a is the high-frequency component of the image after improved Sobe edge detection; is the standard deviation.

For signal models based on equation (14), the maximum posterior probability available is estimated as

$$x_1(m,n)=\begin{cases} z_1(m,n)-\mathrm{sgn}\left[z_1(m,n)\right]T_0 & \left|z_1(m,n)\right|>T_0 \\ 0 & \left|z_1(m,n)\right|>T_0 \end{cases} \tag{16}$$

Where the optimal threshold is:

$$T_0=\sqrt{2}\sigma y_1^{\,2}/\sigma_x \tag{17}$$

The edge estimation given by equations (16) and (17) is characterized by: when the amplitude of the edge of the image is greater than the threshold, the difference between the two is used as the edge estimate, so as to have a stronger noise reduction function.

In order to obtain the best estimate of the edge signal by equation (16), the value needs to be determined, so the value of the sum is calculated separately.

Assuming that the image size is N×N, the values estimated by the median method are:

$$\sigma_{y_1}=\frac{median\left[\left|z_1(m,n)\right|\right]}{0.6745} \qquad 1\leq m,n\leq N \tag{18}$$

Where median is an operation that takes the median value. definition

$$\sigma_{x_1}{}^2=\sigma_x{}^2+\sigma_{y_1}{}^2 \tag{19}$$

$$\sigma_{z_1}{}^2=\frac{1}{N^2}\sum_{m=1}^{N}\sum_{n=1}^{N}z_1^{\,2}(m,n) \tag{20}$$

Available

$$\sigma_x=\sqrt{\max\left(\sigma_{x_1}{}^2-\sigma_{y_1}{}^2,0\right)} \tag{21}$$

Substitute the estimate of the sum given by equation (18) and equation (21) into equation (16) to obtain the threshold T0, which is the optimal threshold.

Compared with the traditional Sobel edge detection algorithm, the biggest advantage of the above method is that it can effectively eliminate noise, retain the real edge of the image after edge detection as much as possible, and achieve a better edge detection effect.

The main steps to improve the Sobel edge detection operator method are:

(1) Discrete convolution of the improved 8 direction templates with the orbital image matrix;

(2) Use the maximum value of the convolution operation result as the new gray value to replace the gray value of the original pixel;

(3) Using the maximum posterior probability estimation method of the edge, the optimal threshold T0 is selected, and the new grayscale image is binarized to obtain the binarized image.

4. Experiments and analysis

4.1 Experimental flow

In order to verify the effectiveness of the improved Sobel operator proposed in this paper, the grasping of small workpieces on the actual production line is simulated, noise is added to the original grayscale map and filtered processing is performed, the filtered grayscale image is obtained, the histogram of the original grayscale image and the grayscale image after adding noise and filtering is compared, and the edge detection operators behind the improvement are used to detect the edges using 5 classical edge detection operators and the Sobel operator behind the improvement, and the results are analyzed after obtaining the data, which verifies the effectiveness of each detection method. The experimental flow is shown in Figure 6:

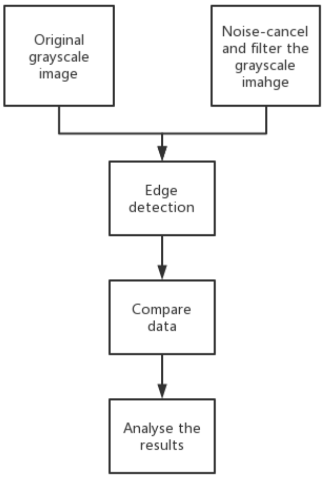


Fig.6. Experimental flow

Take the small workpiece image collected in real time on the mobile production line as the original image in the format of png, as shown in Figure 7 as the small workpiece gray scale diagram image:

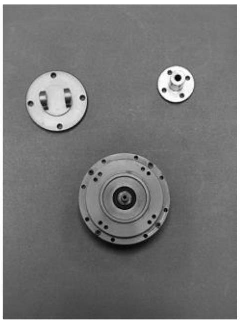


Fig.7. Grayscale image of a small workpiece

Add Gaussian noise with a variance of 0.02 to the small workpiece grayscale image, and use Gaussian filtering of the 3×3 template to process the grayscale image of the noisified workpiece, and obtain the Gaussian filtered grayscale image as shown in Figure 8:

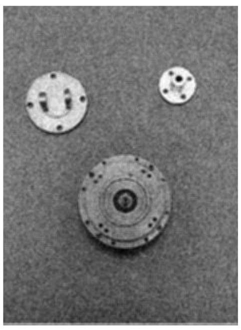


Fig.8. Grayscale image after Gaussian filtering

4.2 Grayscale image results and analysis

The image edge detection is the use of differential operators to extract the edge of the image, and the final edge detection result is expressed as a binaryized image, at this time there are only two kinds of pixels in the image, the pixel values are 0 and 1, where 0 represents black, that is, the use of non-edge pixels as a background, 1 represents white, that is, the edge of the target in the figure, so as to clearly display the image after edge detection.

The grayscale histogram [7] describes the drawing statistics of an image, which is mainly used in processing processes such as image segmentation and image grayscale transformation. Mathematically it is a function about grayscale, such as let x represent the gray value (generally $0 \le x \le 255$), then f(x) represents the number of pixels with gray value x on an image when x is a specific grayscale, and it should be noted that the function f(x) here is a discrete function. Graphically, the grayscale histogram is a two-dimensional graph, with the abscissa representing the gray value (gray level) and the ordinate representing the number or probability that pixels with each gray value or gray level appear in the image.

As shown in the figure is a histogram of two grayscale images, where the change in gray value and the overall grayscale distribution are quite different, as shown in Figure 9-b, the grayscale change of the image after using Gaussian filtering is more gentle, the peak is around 1400, and the peak before filtering is about 1600.

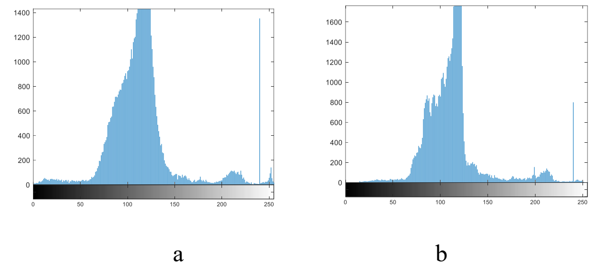


Fig.9. Histogram of two grayscale images

Five classical edge detection operators and an improved Sobel operator were used to detect the edges of the grayscale images of small workpieces [8], respectively, and the detection results are shown in Figure 10.

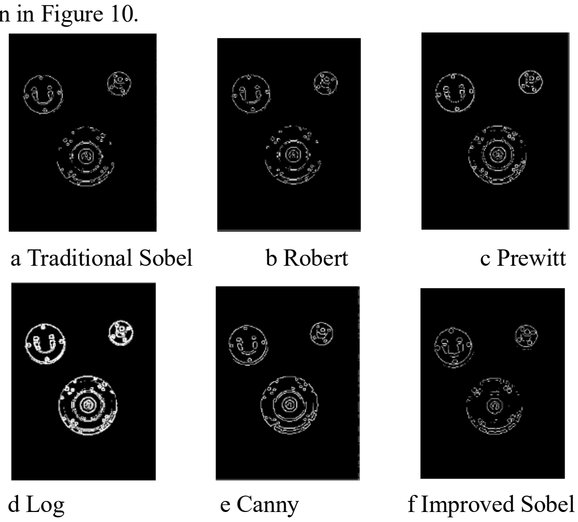


Fig.10. Histogram of two grayscale images

Fig. 10-a~e are the results of the detection of the edge of the grayscale image of a small workpiece by the conventional Sobel operator, the Robert operator, the Prewitt operator, the Log operator and the Cany operator. Figure 10-a~c has a similar effect on the edge detection effect of the original grayscale image of the small workpiece, and maintains a high accuracy for the detection of the parts with more obvious gradients, but it is impossible to accurately detect some parts with small gradient changes, and there are breakpoints that cannot keep the edges of the small workpiece

coherent, and the edge detection effect of Figure 10-a is slightly worse than that of Figures 10-b and Figure 10-c, with more unrecognizable edge points. Fig. 10-d Although Fig. 10-d compared with Fig. 10-a, Fig. 10-b and FIG. 10-c, the edge point of the small workpiece image is recognized more, but some noise is also mistakenly identified as the edge point, and the detection result is worse than that of other differential operators. Figure 10-eCanny operator is compared to Figure 10-d to identify more noise, although the edge point detection is equally excellent, but still does not meet the requirements, this is because the Canny edge detection operator will identify the disorder when it encounters noise after identifying high-intensity edges, it is difficult to protect the edges of low and medium intensity, and the edge width of the Sobel operator detected after the improvement of Figure 10-f is small, the edges with small gradient changes can be detected, the edge continuity is high, and the noise suppression effect can be achieved as much as possible , the detection effect is the best.

4.3 Grayscale images are calculated for two types of pixel ratios

The grayscale image of the small workpiece after edge detection is measured by the frequency ratio of two types of pixels, processing time, variance, mean gray scale, entropy and so on. After edge detection, the small workpiece image becomes a binary image, and each image contains only two-pixel values of 0 and 1, and the number of differences is large. The traditional Sobel operator, Robert operator, and Prewitt operator have more pixels with 0 values, that is, more black areas, while the Log operator and The Cany operator have more pixels with pixel values of 1, that is, more areas are white. The use of histogram to clearly display the ratio of the number of two pixels, because the number of pixels in the grayscale image is larger, so take the ratio of the two pixels to more intuitively and conveniently represent the difference in quantity, so that 0 pixels divided by 1 pixel, the greater the ratio, indicating that the more 0 pixels in the black figure, the smaller the ratio, indicating that the white 1 pixel more.

As shown in Figure 11, the ratio of the traditional Sobel operator, Robert operator, Prewitt operator and Log operator is larger, the pixel value of the pixel value is 0 is more, the ratio of the Canny operator and the improved Sobel operator is smaller, the pixel value of the pixel value is more, but the first three more noise next to the true edge of the workpiece image is also recognized, and the Log operator even mistakenly recognizes the clutter noise point outside the workpiece as the edge of the image.

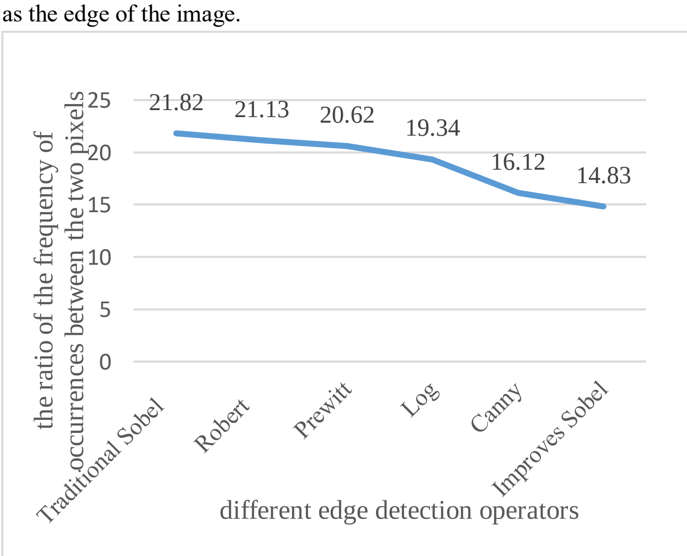


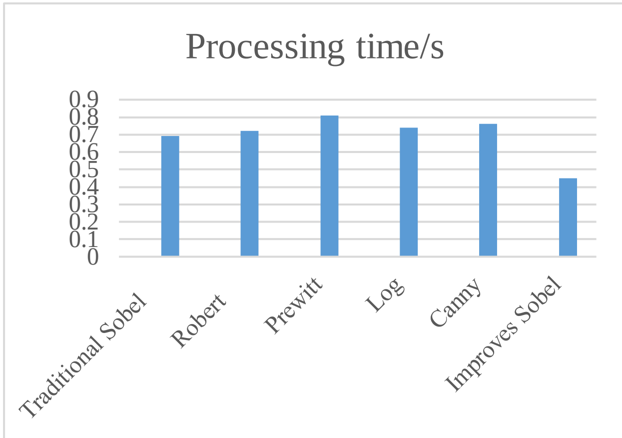
Fig.11. Six operators detect the frequency ratio of the latter two pixels

The Canny operator is more due to the inability to add noise while protecting the low-intensity edges and recognizing the noise as edges, so there are more pixels with pixel values of 1, while the improved Sobel operator does as much as possible to filter the noise and identify the real image edges that are more consistent with the experimental results.

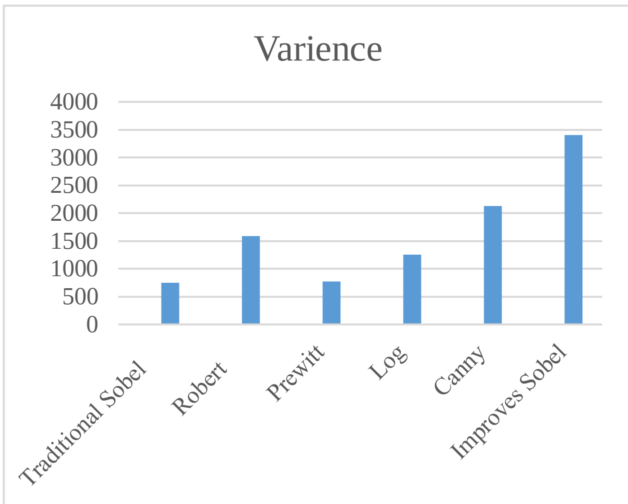
Table 1 measures the processing time, variance, mean grayscale and entropy of the images after the operators are detected, which further confirms the excellent performance of the improved Sobel operator in edge detection.

Tab. 1. Comparison of the results of the edge detection operator

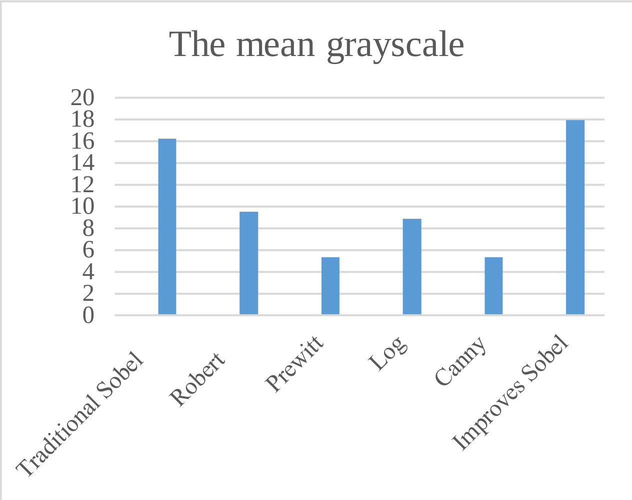
Case	Traditional Sobel	Robert	Prewitt	Log	Canny	Improves Sobel
Processing time/s	0.69	0.72	0.81	0.74	0.76	0.45
variance	752.6327	1.5908e+03	766.2513	1.2523e+03	2.1237e+03	3.4011e+03
The mean grayscale	16.256	9.5397	5.3511	8.8905	5.3531	17.9679
Entropy/bit	0.7673	0.9548	0.7601	1.1492	1.9820	1.2916



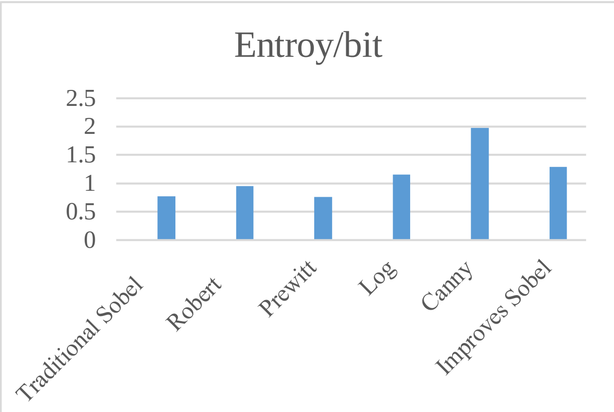
a



b



c



d

Fig.12. Comparison of edge detection operator results

Available from the graph, the improved Sobel operator edge detection algorithm has a short processing time, which is 34.8% lower than the second shortest traditional Sobel edge detection, indicating that the algorithm can effectively speed up detection speed; The variance is the highest value, which shows that the algorithm can better increase the contrast of grayscale images while denoising, which is conducive to edge detection and recognition. The mean grayscale is also the highest value among the six operators, indicating that the algorithm can better increase the average brightness of the grayscale image and improve the image quality; Entropy is the highest value in addition to Canny edge detection, indicating that the algorithm can better enrich the amount of grayscale image information, and The Cany edge detection algorithm, although the entropy data is relatively excellent, but it is easy to misjudge noise as a boundary, and the double threshold method based on gradient amplitude is often difficult to protect low-intensity edges while suppressing noise, which affects the effect of edge detection to a certain extent, combined with the data in Figure 15 of Table 2 after that, or the improved Sobel edge detection algorithm is selected for edge detection.

4.4 Grayscale image results and analysis after noise filtering

In the actual production environment, the acquisition of workpiece images is very easy to usher in noise interference, for this reason, this paper simulates the actual production line conditions to add Gaussian noise with an average value of 0, variance of 0.02 and Gaussian filtering, filtering and then using 6 kinds of operators for edge detection, edge detection results as shown in Figure 13:

a Traditional Sobel b Robert c Prewitt

d Log e Canny f Improved Sobel

Fig.13. Graph of the detection results of six edge detection operators after noise filtering

Fig. 13-a~e are the results of the detection of the edge of the grayscale image of the small workpiece after noise-canceling filtering by the conventional Sobel operator, the Robert operator, the Prewitt operator, the Log operator and the Canny operator. Figures 13-a, 13-b and 13-c have similar effects on the edge detection effect of the grayscale image after noise-added filtering of small workpieces, and the detection of some parts with more obvious gradients still maintains a certain accuracy, but it is impossible to accurately detect some parts with small gradient changes, and there are breakpoints, which cannot maintain edge coherence [9], and even some of them have continuous breakpoints. Figure 13-d shows that since the addition of Gaussian noise identifies more noise as the edge of the workpiece than the previous gray scale plot results, the detection results are significantly worse than other differential operators, and are also excluded from consideration. Figure 13-e identifies other noise points at the edge of the image as the edge of the image. The improved Sobel operator in Figure 13-f is more complete than the edge detected by other operators, and the gradient profile of the edge of the small workpiece edge is detected, the edge continuity is strong, and the noise inhibition effect is achieved, and no misidentification is carried out, and the detection data can be obtained from Figure 14 and Table 2, and the improved Sobel operator has the best detection effect.

4.5 The calculation of the two types of pixel ratios of grayscale images after noise filtering

The grayscale image of the small workpiece after noise-raising filtering after edge detection is measured by two types of pixel occurrence frequency ratio, processing time, variance, gray scale mean, entropy and other data measurements. After noise filtering and edge detection, the small workpiece image becomes a binary image. Figure 14 is the calculation result of the frequency ratio of two types of pixels, the traditional Sobel operator, Robert operator, Prewitt operator and Log operator have a larger ratio, the pixel value of the pixel value is more, the ratio of the Canny operator and the improved

Sobel operator is smaller, the pixel value of the pixel value is more, but the traditional Sobel operator and the Prewitt operator cannot accurately identify the edge of the small workpiece image, resulting in missing edges. Robert operators even recognize the edge of the stage of the small workpiece, the naked eye visible recognition error also makes it out of consideration, the Log operator and the Cany operator can not add noise while protecting the low intensity edge and the noise is also recognized as the edge, so they detect more pixels with a pixel value of 1, while the improved Sobel operator does as much as possible to filter the noise and identify the real image edge and gradient profile.

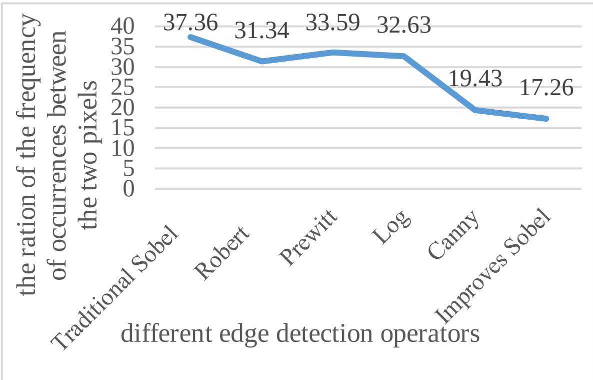
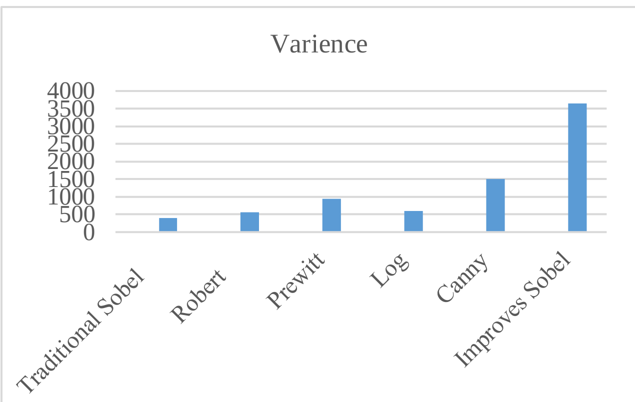


***Fig.14.**.Six operators detect the frequency ratio of the latter two pixels*

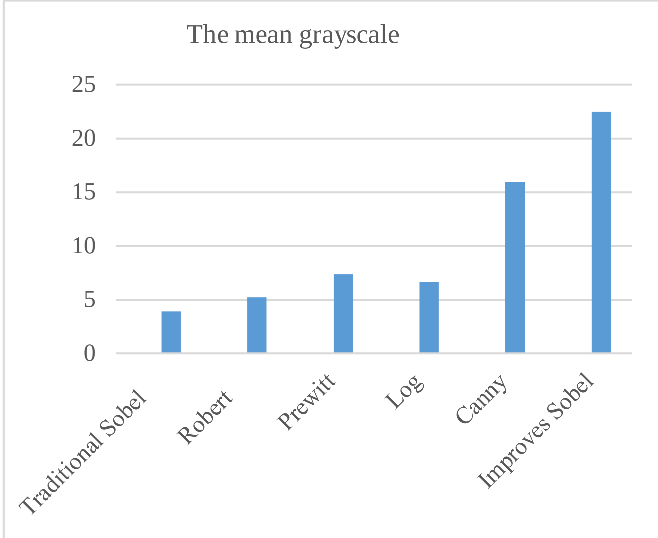
Table 2 measures the processing time, variance, gray scale mean, and entropy of the images after the operators are detected, which further confirms the reliability of improved Sobel operators in edge detection.

Tab.2. Comparison of the results of the edge detection operator

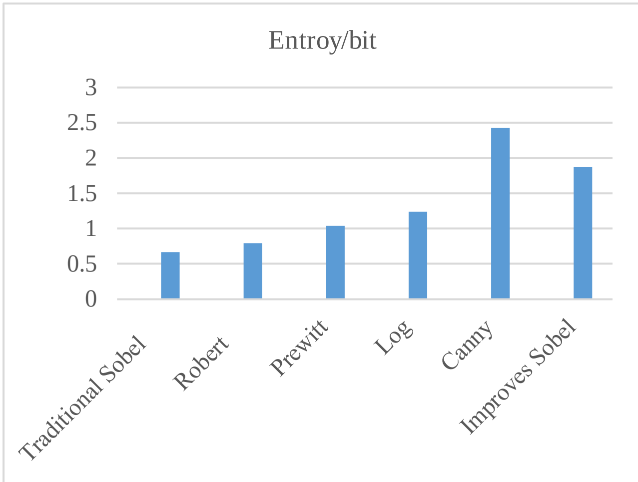
Case	Traditional Sobel	Robert	Prewitt	Log	Canny	Improves Sobel
Processing time/s	0.72	0.76	0.86	0.77	0.79	0.49
variance	405.8776	559.4134	936.7659	603.6869	1.4983e+03	3.6528e+03
The mean grayscale	3.9249	5.2148	7.3737	6.6591	15.9087	22.4918
Entropy/bit	0.6687	0.7968	1.0354	1.2385	2.4252	1.8701



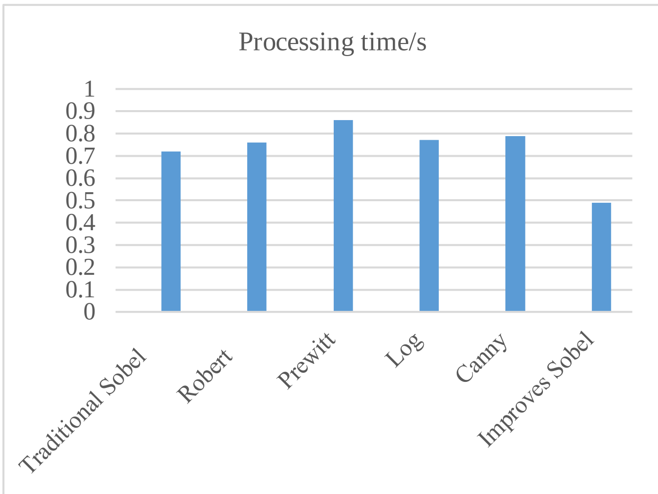
a



b



c



d

Fig.15..Comparison of edge detection operator results

The improved Sobel operator edge detection algorithm[10] has a short processing time, which is 31.9% lower than that of the second shortest traditional Sobel edge detection, indicating that the algorithm can effectively speed up detection; The highest variance is the highest value, indicating that the algorithm can increase the contrast of grayscale images while denoising, which is conducive to edge detection and recognition. The mean grayscale is also the highest value among the six operators, indicating that the algorithm can better increase the average brightness of the grayscale image and improve the image quality; Entropy is the highest value except for Cany edge detection, indicating that the algorithm can better enrich the amount of grayscale image information, and although the Entropy data of The Canny edge detection algorithm is relatively excellent, it is easy to misjudge the noise as a boundary, and the double threshold method based on gradient amplitude is often difficult to protect the low-intensity edge while suppressing the noise, which affects the effect of its edge detection to a certain extent, so it is still the use of the improved Sobel edge detection algorithm for edge detection.

5. Summary

In this paper, aiming at the limitations of classical edge detection differential operators, based on the traditional Sobel edge detection algorithm, the direction template is improved by adding six detection directions of 22.5°, 45°, 67.5°, 112.5°, 135° and 157.5°, so that the algorithm has greater advantages in terms of continuity, detail and real-time degree to make up for the shortcomings of classical edge detection differential operators, and finally effectively improves the detection effect of classical edge detection differential operators.

Acknowledgements

This project is grateful to the State Key Laboratory of Robotics For its self-funded project (2020-Z07), the National Key Research and Development Project (YFC08332032), and the Jiangsu Provincial Key Construction Laboratory for its financial support (JSKLESS201707).

References

Ren S Q,He K M,Girshick R,et al．Faster R－CNN: Towards Real Time Object Detection with Region Proposal Networks [J]．IEEE Transactions on Pattern Analysis＆Machine Intelli- gence,2015,39(6):1137－1149

Cai Xinyue,Zhou Yang,Hu Xuefei. Intelligent Detection Method for Small Targets reconstructed by super resolution[J].Advances in Laser and Electronics,2022(7):36-37.

LIU Shize,FAN Shurui,GUO Shuwei. Research on Sensor Network Edge Detection for Environmental Monitoring[J].Modern Electronics Technology,2022,45(16)

Hiemann Alexander;Kautz Thomas;Zottmann Tino;Hlawitschka Mario. Enhancement of Speed and Accuracy Trade-Off for Sports Ball Detection in Videos—Finding Fast Moving, Sensors,2021,21：3214-3214.

Ma,et al., Enhancement of Speed and Accuracy Trade-Off for Sports Ball Detection in Videos—Finding Fast Moving. Sensors, 2021. 1(1): p. 3214-3214.

Zhang,et al., Research on image acquisition optimization of football robot vision system. Mechanical design and manufacturing, 2009. 1(2): p. 157-159.

Xiang,et al., Research on YUV to RGB color space conversion algorithm. Modern electronic technology, 2012. 35(22): p. 22-23.

Xing,et al., Research on image segmentation of dirty oil based on matlab and YUV color spaces.Modern electronic technology, 2012. 1(1): p. 23-24.

Huang,et al., Positioning algorithm based on minimal external rectangle and Hough transform.Combining machine tools with automated machining technology, 2021. 1(1): p. 8-9.

Lan,et al., Basketball goal recognition research based on image analysis. Journal of Huaihua University, 2021. 1(1): p. 10-11.

Li,et al., Multi-robot collaborative SLAM research based on RGB-D camera. Changchun University of Science and Technology, 2020. 1(1): p. 10-11.

Yang, Z., et al., Back-stepping Sliding Mode with Unidirectional Auxiliary Surfaces for HSV with Attitude Constrains. International Journal of Applied Mathematics in Control Engineering, 2018. 1(2): p. 187-193.

Yu, X., et al., Peak-Valley Detection and Step Counting Method Based on Kalman Filter on Android Smartphones. International Journal of Applied Mathematics in Control Engineering, 2018. 1(2): p. 200-205.

Guo Jingwei is currently pursuing a master's degree in the School of Electrical and Control Engineering, Shenyang Jianzhu University in Shenyang, China. In 2020, he received a bachelor's degree from Shenyang Urban Construction College. His main research interests are in the areas of object recognition, image segmentation, and more.

Jian Liu is currently a professor, doctoral and graduate supervisor at the School of Electrical and Control Engineering, Shenyang Jianzhu University. Her main research interests are in the areas of intelligent control, electrical drives and automation.

Yang Zhou is currently pursuing a master's degree in the School of Electrical and Control Engineering, Shenyang Jianzhu University, China. In 2020, he received a bachelor's degree from Shenyang Ligong University. His main research direction is high-voltage electric field control 3D printing.