An Edge Detection of Equipment Image Based on Improved Canny Operator

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Abstract. Because of the image of the equipment in the data center room may have many problems such as noise and significant influence between equipment, the research on the edge detection of equipment image is important for the research of feature extraction and target recognition. In this paper, based on Canny operator edge detection, improvements are made by using morphological filter instead of Gauss filter for noise reduction. The experimental results show that the method in this paper has a better effect in filtering denoising and edge preserving.

Introduction

With the increasing business volume, the number, scale and complexity of the objects that data centers need to manage are increasing exponentially. The equipment in data center room is easy to age, and often fails, which brings great security risks. Due to the high frequency and repeatability of work, the traditional manual monitoring methods can’t meet the business needs, so the data center machine room inspection robot came into being. There are a large number of cables, servers, storages, switches, etc. in the data center room. The inspection robot needs to solve the problem of equipment image recognition and fault signal judgment, so equipment image preprocessing becomes an essential part. As a classic technology of image preprocessing, image edge detection has been actively in computer vision\cite{1,2}. Edge is the most basic feature of image, and most of the information of image exists in the edge. Because the equipment image in the data center room may have many problems such as noise and significant influence between equipment, the research on the edge detection of equipment image is very important for the research of feature extraction and target recognition.

The edge of an image is generally the place where the gray or color of the image changes dramatically. It is discontinuous in the gray level. It is a collection of pixel values whose gray value has a roof change or step change.\cite{2} The image roof change or step change is generally described by the size of first derivative or second derivative of gray image, so the image edge detection methods are mainly divided into first-order differential and second-order differential image edge detection operator. Although there are many algorithms of image edge detection, most of them have some limitations. For example, Roberts operator is a kind of operator that uses local difference operator to find the edge. Because it is sensitive to noise, it is only suitable for images with steep edge and low noise. Sobel operator takes the maximum value of two convolution kernels, vertical and horizontal, as the output. Because the calculation direction is single, it does not strictly separate the main body and background of the image, so it is not suitable for complex images. Prewitt operator can smooth the edge and reduce the sensitivity of image direction.\cite{3} Compared with other operators, Canny operator has advantages in signal-to-noise ratio, positioning accuracy and single edge response, so it is widely used in the field of digital image processing. However, the image edge detection based on Canny operator is very sensitive to noise and has some shortcomings. In recent years, many scholars have proposed an improved algorithm based on Canny operator. WANG Bing uses the mean value and variance of the image to determine the high and low thresholds.\cite{4} ZHAO Hui-li uses wavelet transform to enhance the edge of the image, eliminating the weak point of traditional Canny algorithm in edge detection of weak edge and discontinuous edge image.\cite{5} In this paper, on the basis of Canny operator edge detection, morphological filter is used instead of Gaussian filter, and gradient amplitude is calculated in four directions to reduce the impact of noise. The experimental results show that the method in this paper has a better effect in filtering denoising and edge preserving.
Canny Operator

Canny operator is an edge detection algorithm developed by John F. Canny in 1986. Although it has been many years, it is still one of the classic algorithms of image edge detection. Firstly, Canny operator edge detection algorithm uses the first derivative of Gaussian function in any direction to smooth the image; secondly, it calculates the gradient amplitude and direction of the smoothed image, and uses non maximum suppression technology to suppress the interference value of the local area; finally, it sets high and low thresholds to remove the false edge and connect the true edge. The edge detection flow of Canny operator is as follows:

Gaussian filtering smooths the image. The gray-scale image \( I(x, y) \) is obtained after the gray-scale conversion of the original image. The traditional Canny algorithm uses the Gaussian distribution function \( g(x, y) \) as the smoothing factor to convolute the horizontal and vertical directions of \( I(x, y) \), respectively, to obtain the filtered image \( f(x, y) \).

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

\[
f(x, y) = G(x, y) \ast I(x, y)
\]

The value of variance \( \sigma \) determines the degree of image smoothness. If the value of \( \sigma \) is large, the signal-to-noise ratio of image is high, and the accuracy of edge location is low; otherwise, the situation is opposite. Therefore, the reasonable value of \( \sigma \) is the key factor of image edge positioning accuracy and signal-to-noise ratio.

Calculate the gradient amplitude and direction. The traditional Canny algorithm uses \( 2 \times 2 \) neighborhood first-order partial derivative finite difference to calculate the gradient amplitude and direction of the filtered image \( f(x, y) \). The methods for calculating the partial derivatives in \( X \) and \( Y \) directions are shown in formula (3) and formula (4), respectively

\[
P_x(x, y) = [f(x, y + 1) - f(x, y)]/2 + [f(x + 1, y + 1) - f(x + 1, y)]/2
\]

(3)

\[
P_y(x, y) = [f(x, y) - f(x + 1, y)]/2 + [f(x, y + 1) - f(x + 1, y + 1)]/2
\]

(4)

The calculation method of gradient amplitude and direction is shown in formula (5) and formula (6) respectively:

\[
M(x, y) = \sqrt{P_x^2(x, y) + P_y^2(x, y)}
\]

(5)

\[
\theta(x, y) = \arctan\left[\frac{P_y(x, y)}{P_x(x, y)}\right]
\]

(6)

Non maximum suppression. The essence of non-maximum suppression is to find the local maximum value of the pixel, retain the point with the largest local amplitude change, and suppress the interference value in the local area. Its basic idea is: the gradient amplitude \( M(x, y) \) of the point \( (x, y) \) on the image is compared with the gradient amplitude of two adjacent pixels along the gradient line direction. If it is less than, it is considered that the pixel is not an edge point.

Double threshold edge connection. Canny algorithm uses two thresholds, i.e. a high threshold \( T_h \) and a low threshold \( T_l \) to distinguish edge pixels. \( T_h \) and \( T_l \) can be selected according to prior knowledge. The image edge judgment criteria are as follows: for the points \( (x, y) \) in the candidate edge image, if \( M(x, y) \) is greater than \( T_h \), the recognition point \( (x, y) \) is the edge point; if \( M(x, y) \) is less than \( T_l \), it is determined that \( (x, y) \) is not the edge point; if \( T_l < G(x, y) < T_h \), the recognition point \( (x, y) \) is the candidate edge point, then it is necessary to determine whether the gradient amplitude of the neighbor of the pixel point is greater than \( T_h \), if it is greater than, it is the edge point, otherwise the opposite.
Improved Canny Algorithm

The image of the equipment in the data center room is complex, so it is difficult to get satisfactory results by using the traditional Canny edge detection algorithm. In this paper, morphological filtering is used instead of the Gaussian filtering of Canny edge detection to reduce the noise. At the same time, four directions are used to calculate the gradient amplitude to reduce the impact of noise.

Morphological Filtering

As a new subject of image processing and analysis, mathematical morphology was first founded in 1964 by G. Matheron and J. Serra on the basis of integral geometry. Mathematical morphology is a nonlinear filtering method in image processing. It is composed of a group of algebraic operators of morphology. It has four basic operations: expansion, corrosion, open operation and closed operation. Morphological operation can be based on binary image and gray image. In this paper, the filter is constructed by gray-scale morphology, and the Gaussian filter of Canny operator is replaced by morphological filter. \( f(x,y) \) is used to represent gray-scale image, \( b(i,j) \) is used to represent structural elements, \( D_f \) and \( D_b \) are used to represent the domain of \( f \) and \( b \) respectively.

The expansion operation is defined as

\[
(f \oplus b)(x, y) = \max\{f(x - i, y - j) - b(i, j) | (x - i, y - j) \in D_f; (i, j) \in D_b \}
\]  

(7)

Corrosion operation is defined as

\[
(f \ominus b)(x, y) = \min\{f(x + i, y + j) - b(i, j) | (x + i, y + j) \in D_f; (i, j) \in D_b \}
\]  

(8)

The expansion operation can expand the white value range and compress the black value range, which is generally used to expand the edge or fill small holes; the corrosion operation can expand the black part and reduce the white part, which can be used to extract backbone information and remove isolated pixels. Through the combination of corrosion and expansion, advanced morphological operations such as opening operation, closing operation can be extended.

The opening operation refers to the corrosion and expansion of image \( f(x, y) \) with structural element \( b(i, j) \), which is defined as:

\[
f(x, y) \circ b(x, y) = [(f \ominus b) \oplus b](x, y)
\]  

(9)

Closed operation refers to expanding image \( f(x, y) \) with structural element \( b(i, j) \) and then corroding it. The definition formula is as follows:

\[
f(x, y) \cdot b(x, y) = [(f \oplus b) \ominus b](x, y)
\]  

(10)

The open operation can effectively filter out the positive noise in the image, especially some small structures. The closed operation can be used to filter out the negative noise, especially the small holes. In general, the combination of open and close operations can achieve better denoising and visual effect than the single morphological open and close operations. In this paper, the morphological filter is constructed as follows:

\[
G_d(x, y) = f(x, y) \circ b(x, y) \cdot b(x, y)
\]  

(11)

The structure element \( b(i, j) \) adopts \( 3 \times 3 \) cross matrix elements:

\[
b(i, j) = \begin{bmatrix}
0 & 1 & 0 \\
1 & 1 & 1 \\
0 & 1 & 0
\end{bmatrix}
\]

Calculation of Gradient Amplitude

The traditional Canny algorithm uses \( 2 \times 2 \) finite difference to calculate the gradient value, which is good for edge location, but sensitive to noise. In this paper, \( 3 \times 3 \) first-order partial derivative finite difference is used to calculate the gradient value and direction. Based on the horizontal and vertical templates of traditional Sobel operator, \( 45^\circ \) and \( 135^\circ \) templates are added to calculate the gradient value and direction.
amplitude. Referring to the principle of Sobel operator, the gradient operators in four directions are constructed, namely, horizontal direction, vertical direction, 45° direction and 135° direction:

\[
\begin{bmatrix}
-1 & -2 & -1 \\
0 & 0 & 0 \\
1 & 2 & 1
\end{bmatrix}
\begin{bmatrix}
0 & 1 & 2 \\
-1 & 0 & 1 \\
-1 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
-2 & -1 & 0 \\
-1 & 0 & 1 \\
0 & 1 & 2
\end{bmatrix}
\begin{bmatrix}
-2 & -1 & 0 \\
0 & 1 & 2
\end{bmatrix}
\]

\(P_x(x,y), P_y(x,y), P_{45}(x,y), P_{135}(x,y)\) is the four gradient components of horizontal direction, vertical direction, 45 direction, 135 direction. In this paper, the gradient amplitude \(M(x,y)\) and the gradient direction \(\theta(x,y)\) are calculated as follows:

\[
M(x,y) = \sqrt{P_x(x,y)^2 + P_y(x,y)^2 + P_{135}(x,y)^2 + P_{45}(x,y)^2}
\]

(12)

\[
\theta(x,y) = \arctan \frac{P_y(x,y)}{P_x(x,y)}
\]

(13)

**Experimental Result**

Hardware and software environment are as follows: Intel Core i7 2.9 GHz CPU, 8GB memory, Matlab 2017. In order to verify the effectiveness of the algorithm, we add the salt-and-pepper noise with 0.005 noise density, set \(T_l = 0.1, T_h = 0.3\), and carry out the edge processing for the image of server equipment in the cabinet of data center machine room.

![Figure 1. Original image.](image1)

![Figure 2. Gray-scale image.](image2)

![Figure 3. salt-and-pepper noise image.](image3)

![Figure 4. Canny algorithm image.](image4)

![Figure 5. Improved Canny image.](image5)
Compared with the experimental results, this algorithm can detect more edge details. This algorithm is less affected by noise, more accurate positioning, clearer than the traditional algorithm, and better edge detection effect.

Conclusion
The traditional Canny edge detection algorithm is easy to be affected by noise, illumination and other factors. We improve the traditional Canny algorithm by replacing Gaussian filter with composite morphological filter to reduce the impact of noise. The experimental results show that the improved algorithm has better detection effect and anti-noise performance than the traditional Canny algorithm.

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