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Application of improved Canny algorithm on the IC Chip pin inspection

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Abstract. Machine vision is widely used in automation detection of chip pins' defect, the accuracy of image edge detection has a very big effect for inspection result. Canny algorithm is a kind of edge detection algorithm which has good comprehensive evaluation, but the Gaussian filter algorithm it used may cause image too smooth and edge fuzzy, and it is very sensitive for impulse noise. This paper proposes an improved switch median filter algorithm, which is applied into Canny algorithm, makes the edge of IC Chip pin more complete and remove noise better. Through experiments, it proved that the method is feasible and effective.

Introduction

In order to satisfy the needs of the development of electronic information industry, today's electronic components encapsulation is developing to miniaturization, chip and high-performance quickly. Surface mounted technology (SMT) as the new generation of electronic assembly technology, has been applied more and more. In the chip packages, defect inspection of the pins is necessary, and it is premise for correct encapsulation [1]. Computer vision technology as a non-contact measurement technology, it has such advantages as non-contact , real-time, flexibility, accuracy and reliability, this is the traditional measuring technique does not have, so it is widely used in chip pins defects detection system.

Edge extraction is very crucial step in the chip pins detection process. The accuracy of edge detection directly affect the accuracy of the inspection results. Therefore, edge detection has become a very important link and has the important status in chip pins detection. There are many algorithm is used to detect the edge of the objects in planar images in digital image processing, Such as Robert algorithm, Prewitt algorithm, Sobel algorithm, Laplace and LOG algorithm of the algorithm etc[2].Usually, these operators are simply easy to realize and real-time enough, but more sensitive to noise, anti-jamming performance is poor and edge is not enough fine[3].

Canny was proposed based on the optimization algorithms of edge detection operator in 1986.It puts forward three standards so far most strict definition of edge detection, has the very good SNR and precision, therefore, it has been widely used. But we find that the filter used in Canny is Gaussian function, which can cause excessive original image smooth, on the other hand, can cause dispersion-decreasing edge easily lost. This paper mainly aims at the problems, study to improve the Canny algorithm based on research of edge detection algorithm. Introducing the double threshold value judgment method of noise based on direction information and switch median filtering into Canny to achieve edge detection of image. Experiments show that the algorithm enhances the precision and accuracy of the edge.

The theoretical of Canny algorithm[4]

Canny analysis the classic edge detection operators and edge detection application, find that good edge detection algorithm should has the following three characteristics:

(1) Good edge detection performance

Mean that the algorithm has low false rate of edge points judgment. The mathematical expressions of SNR is:

$$SNR(f)=\frac{\left|\int_{-W}^{+W}G(-x)f(x)dx\right|}{n_0[\int_{-W}^{+W}f^2(x)dx]^{1/2}} \tag{1}$$

Where $f(x)$ is the impulse response of the filter which border is $[-w,+w]$, $G(x)$ representative edge, n_0 is the RMS of the Gaussian noise. If the SNR is bigger, then the quality of edge is better.

(2) Good location performance

The position of edge points as near the center position of the real edge. The mathematical expression of the positioning performance is:

$$L(f)=\frac{\left|\int_{-W}^{+W}G'(-x)f'(x)dx\right|}{n_0[\int_{-W}^{+W}f'^2(x)dx]^{1/2}} \tag{2}$$

Where $f'(x)$ and $G'(-x)$ is the derivative of $f(x)$ and $G(-x)$.Because the $E[x_0^2]$ smaller, the edge detection more accurate, this rule is to find filter function $f(x)$,make $L(f)$ as far as possible big.

(3) Single edge response

This rule is every edge points have one and only a response, boycott the emergence of untrue edge farthest. Two nearby zero distance between junctions of noise which filter by $f(x)$ is:

$$x_{zc}(f)=\pi\left\{\frac{\int_{-\infty}^{+\infty}f'^2(x)dx}{\int_{-\infty}^{+\infty}f''^2(x)dx}\right\}^{1/2} \tag{3}$$

Then filter to the edge of the maximum response between the average distances is:

$$x_{\max}(f)=2x_{zc}(f)=kW \tag{4}$$

This shows, just make sure the k, we can confirm the maximum number appear in the 2W area. Through this rule, for every edge can ensure to have a unique response and get edge of single pixel wide.

Improved Canny algorithm

The Canny algorithm use Gaussian filtering on image pre-register smooth processing, Gaussian filter coefficients δ must be determined by human, different Gaussian filter coefficients have a great effect on the effect of the image edge detection, coefficients determined by human is hard to meet the requirements of both of noise smooth and protect the edge information. And in computing image gradient amplitude, it is too sensitive to noise, in actual application of easy to cause the loss of some effective edge details and detect the fake edge, therefore higher requirements for the image smooth processing. This shows, the traditional Canny algorithm Gaussian filtering method of edge detection hard to meet the requirements.

According to this problem, people put forward their own solutions. Such as Limy-chi use filter which $\delta=1$,use Wiener filter and improve SNR by choose high and low threshold value[6].Also some people performance wavelet analysis[7],fuzzy enhancement[8],gradient histogram[9] etc to Canny algorithm, and achieved certain effect.

This paper's references [10] proposed a switch median filtering method based on sort of the threshold, this paper will do for its further improvement, replace traditional Canny algorithm with an improved switch median filter which based on direction information and with double threshold noise discriminate function. The simulation results show this method has been a very good effect.

Improved median filtering algorithm

(1)Traditional median filtering algorithm

Assume x_{ij} is the gray value of (i, j) in a digital picture, $Wn[x_{ij}]$ is the window center of (i, j) ,this window is size of $n \times n = 2N + 1$, $med(Wn[x_{ij}])$ is take the mid-value of all points in the window $Wn[x_{ij}]$. y_{ij} is the output of (i, j) which filter by median filtering algorithm, then the output of traditional median filtering algorithm is:

$$y_{ij} = med(W_n[x_{ij}]) \tag{5}$$

All pixels adopt uniform processing method in this method, noise point can be restored, but other non-noise points were filtering processed in the same time. This treatment may result in signal point degradation, such as cause the loss of fine line, edge and pointedness; even destroy subjective image visual effect.

(2)Switch median filtering method

Based on the above shortcomings of traditional median filter, this paper introduced a kind of improved switch filter structure. This filter first to judge the monitoring point is noise or not, filtering process it until determines it is noise point. If it is not noise, is not to filter. This method can filter the noise effectively, and protect edge information well. The mathematical expression of this filter is:

$$y_{ij} = \begin{cases} x_{ij} & ;x_{ij} \notin noise \\ med(Wn[x_{ij}]) & ;x_{ij} \in noise \end{cases} \tag{6}$$

(3)Judgment of noise point based on directional information

Laplacian fuzzy logical median filter is improved in this paper. In an image, the closer two points is, the gray correlation of them is bigger. Therefore, this paper change the original convolution kernels to the new convolution kernels, in the new convolution kernels, the weights are bigger when the point is closer to the checkpoints. These new kernels also added judgment of four directions. These convolution kernels are shown as shown in fig.1.

0	0	-1	0	0
0	0	-2	0	0
0	0	6	0	0
0	0	-2	0	0
0	0	-1	0	0

0	0	0	0	0
0	0	0	0	0
-1	-2	6	-2	-1
0	0	0	0	0
0	0	0	0	0

0	0	0	0	-1
0	0	0	-2	0
0	0	6	0	0
0	-2	0	0	0
-1	0	0	0	0

-1	0	0	0	0
0	-2	0	0	0
0	0	6	0	0
0	0	0	-2	0
0	0	0	0	-1

-1	0	0	0	-1
0	-2	0	-2	0
0	0	6	0	0
0	0	0	0	0
0	0	0	0	0

-1	0	0	0	0
0	-2	0	0	0
0	0	6	0	0
0	-2	0	0	0
-1	0	0	0	0

0	0	0	0	0
0	0	0	0	0
0	0	6	0	0
0	-2	0	-2	0
-1	0	0	0	-1

0	0	0	0	-1
0	0	0	-2	0
0	0	6	0	0
0	0	0	-2	0
0	0	0	0	-1

-1	0	0	0	-1
0	-2	0	-2	0
0	0	12	0	0
0	-2	0	-2	0
-1	0	0	0	-1

Fig.1 Nine convolution kernel

Then, we compute the minimum of these convolution results, and compare it with threshold value T,

$$r_{ij} = \min\left\{\left|x_{ij} \otimes K_p\right|; p = 1,2,...,9\right\} \tag{7}$$

Where K_p is the p-th kernel, $\otimes$ is convolution algorithm.

This noise judge method considered more neighborhood information of testing point adequately, so it has more strong ability of judgment for salt&pepper noise. Noise is mostly concentrated in the flat part of the image, and in order to protect the edge and other information, so this paper use smaller threshold T1 to judge noise in the flat part and use bigger threshold T2 in the other parts.

(4)Judgment of the flat part of the image[10]

First, this paper sort the pixel point in $W_n[x_{ij}]$, receive $x_{ij}^{(1)},...,x_{ij}^{N+1},...x_{ij}^{2N+1}$, in which

$$\begin{aligned} x_{ij}^{(1)} &= \min(W_n[x_{ij}]) \\ x_{ij}^{(2N+1)} &= \max(W_n[x_{ij}]) \end{aligned} \tag{8}$$

Setting threshold Biff formula (9) is satisfied, thinks that this testing point is in the flat area.

$$\left| x_{ij}^{1+b} - x_{ij}^{2N+1-b} \right| \le TB \tag{9}$$

Where b is the position offset of sort, it is 7 in this paper's is the threshold and it is 4 in this paper.
(5)Output of the filter in this paper

Use 5×5 filtering window in this paper, the boundary pixels of images are can't filter by the method proposed in this paper, so we filter them by the traditional median filter. The output of the filter in this paper is

$$y_{ij} = \begin{cases} med(W_3[x_{ij}]) & ;(i,j) \in \{i,j \mid i \le 2 \cup i \ge m-1 \cup j \le 2 \cup j \ge n-1\}, \\ custommed(W_5[x_{ij}]) & ;(i,j) \in others, \end{cases} \tag{10}$$

Where (i,j) is the testing point, $custommed(W_5[x_{ij}])$ is the filtering operation use the method proposed in this paper.

Calculate amplitude and direction of the gradient

Finite difference of first-order partial derivative in 2×2 contextual is used in Canny algorithm to compute the gradient's amplitude and direction of the image after smoothed[5].The gradient amplitude M(i,j) and gradient direction $\theta(i,j)$ of pixel (i,j) in the image is

$$M(i,j) = \sqrt{P_x(i,j)^2 + P_y(i,j)^2} \tag{11}$$

$$\theta(i,j) = \arctan(\frac{P_y(i,j)}{P_x(i,j)}) \tag{12}$$

Where $P_x(i,j)$ and $P_y(i,j)$ represent the partial derivative of the pixel along x and y directions. $M(i,j)$ reflects the edge intensity of the point (i,j), $\theta(i,j)$ is the normal vector of (i,j) and it is perpendicular to the direction of the edge.

Non-maximum suppression of gradient amplitude

For ladder amplitude image array $M(i,j)$, if $M(i,j)$ is bigger, shows its image gradient value is bigger, but this is not enough to determine whether the edge points. In order to accurately determine the edge points, must to detail the roof of amplitude image, keep only the points which amplitude local change is the biggest. On-maximum suppression gets thinning edge after inhibit all gradient amplitude on the gradient direction which is not roof peak. In gradient amplitude image G, Canny algorithm interpolate along the gradient direction in 3×3 neighborhood where point (i,j) is the center, if point (i,j)'s gradient amplitude is bigger than the two interpolations along directional $\theta(i,j)$,then sign the point (i,j) as candidate edge point, otherwise, sign it as non-edge point. So, we can get candidate edge image.

Double thresholds detection and edge joint

Determine two thresholds T_1 and T_2(T_1<T_2) for the candidate edge set. Process the non-maximum suppression image with double thresholds, we can get an high threshold process result(image A) and a low threshold process result(image B).Then, connect the edge in image A, when it is endpoint, find the weak edge points in image B to make up the edge clearance of image A.

Experimental results & Conclusions

8 bit image (256 gray level image) is used and select filtering switch threshold T1=150, T2=200. Though using the traditional canny algorithm and the improved canny algorithm proposed in this paper, the image processing results of IC image is showed as fig.2 ~ fig.7.

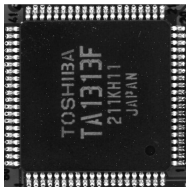

Fig.2 Add 0.2% noise to image

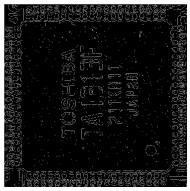

Fig.3 Edge of Chip detected by traditional Canny

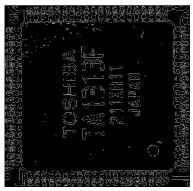

Fig.4 Edge of Chip detected by the algorithm in this paper

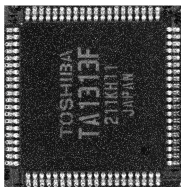

Fig.5 Add 10% noise to image

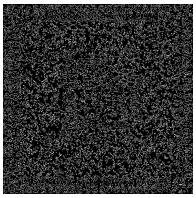

Fig.6 Edge of Chip detected by traditional Canny

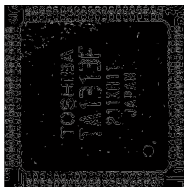

Fig.7 Edge of Chip detected by the algorithm in this paper

From fig.2~4, we can see that traditional canny algorithm can not filter spiced salt noise and is sensitive to noise. But the improved canny algorithm can extract the fuller edge besides filtering the most spiced salt noise. The results of fig.5~7 show the noise filtering effect of the improved canny algorithm further and it can maintain better detailed information of image.

The improved switch threshold filtering algorithm has the advantages of good effect, strong adaptability and simple algorithm. Applying this algorithm to canny edgy detection, we can see the good edge detection effect. Based on the traditional canny edge detection, we reach the aim of noise suppression and edgy maintaining. From the test results, good detection effect can be gotten if this improved canny edge detection algorithm is applied to the chip pins edge inspection.

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