Mixed method of printed circuit board photoelectric image edge information extraction

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Abstract. Due to the noise and fuzziness of printed circuit board (PCB) photoelectric image, a mixed method of image edge information extraction is proposed, which is based on median filter, improved maximum distance between categories (IMDBC) and improved Canny edge detection operator (ICEDO). Firstly, the basic principle and advantages of the maximum distance between categories (MDBC) for image segmentation are analyzed, then the improved MDBC is proposed. Secondly, the ICEDO is discussed, and the basic principle is analyzed. Then, the implementation steps of the image edge information extraction based on mixed method are discussed. The experiments using such noisy and fuzzy images acquired by charge coupled device (CCD) imaging system and microscope are actualized. The experiment results by using the mixed method have lesser noise points, and the image excellent quality coefficients are the highest in the experiment. The excellent quality coefficients are 0.8346 and 0.7981 respectively in two image edge information extraction experiments. Both of the subjective and objective experiment contrasts results verify that the edge information of image can be extracted better by using this method.

1. Introduction
Printed circuit board (PCB) photoelectric image edge contains rich image information. The PCB quality condition can be determined by image edge information extraction, which is widely used in the photoelectric industry [1-5]. Many scholars have done deep research on the edge information extraction of such images, and many achievements have been obtained [1-5]. For example, in 2006, Barbucha et al studied such image edge information extraction by comparing the conventional method and laser imaging tracking method [1]. In 2012, Qiao et al. proposed a method of edge detection based on image fuse in this kind image [2]. In 2016, Wang et al. presented a detection method based on computer vision
for automatic flexible printed circuit (FPC) defect detection, and ensured greater accuracy and more objective detection results compared with traditional human operators [3].

However, owing to various reasons, it may contain the noise and fuzziness in the process of the image acquisition, so it is difficult to extract the image edge information by a single method.

In this paper, aiming at the specific condition of such noisy image, the improved Canny edge detection operator (ICEDO) is used to segment these images after eliminating noise and fuzziness, and the initial target information of the image is obtained, and then the ICEDO is actualized to obtain more complete image edge target information.

2. Basic principle

2.1. Improved maximum distance between categories

The MDBC is a better threshold segmentation method. It is considered as the optimal segmentation in the case of the biggest difference between the target and the background after segmentation [6].

The algorithm steps are listed as follows [6,7]:

An initial threshold \( Th = Th_0 \) is given to make the image be divided into two categories of background and target.

Supposing that the input image function is \( f(x, y) \), the expression of gray mean value between two categories can be expressed as

\[
u_i = \frac{1}{N_{C_i}} \sum_{(x, y) \in C_i} f(x, y) \quad i = 1, 2 \quad (1)
\]

where \( N_{C_i} \) is the number of pixels in the \( i \)th category, and \( i = 1 \) indicates background category, \( i = 2 \) indicates target category.

Relative distance measurement value can be expressed as

\[
S = \frac{(u_2 - Th)(Th - u_1)}{(u_2 - u_1)^2} \quad (2)
\]

To let the image be divided into background category \( C_1 \) and target category \( C_2 \), the optimum threshold value is automatic selected, so that the distance measurement value can be expressed as

\[
S|_{Th=Th'} = \max \{ S \} \quad (3)
\]

The advantages of this segmentation method are obvious, and the target information in the image can be segmented better from the background. However, it does not consider the discreteness of each category, which can not be more comprehensive to reflect the quality of category distinction, the segmentation effect is not ideal.

In order to extract the target information from the background more accurately, the traditional method is improved and a new threshold segmentation method is proposed [7].

The variance between the two categories is used as the discriminant basis in the MDBC, the threshold of the maximum variance between categories is considered to be the best threshold.

The one dimensional variance between categories of pixel gray value between the background and the target objects can be shown as

\[
\delta_i = \omega_b (u_0_i - u_i)^2 + \omega_b (u_{bi} - u_i)^2 \quad i = 1, 2 \quad (4)
\]

where \( \omega_0 \) and \( \omega_b \) represents the proportion of the target and the background, respectively, \( u_0_i \) and \( u_{bi} \) represents the \( i \)th category gray mean value of the target and the background, respectively.
The $\delta_i$ is a measurement of the uniformity of image gray value distribution, the bigger the $\delta_i$, the better the uniformity of the image, that is to say, the smaller the difference between the two parts of the image, so it will have minimum probability of error category between target and background, and it will have the largest distance between the background category and the target object category.

The classified discrete measurement of the corresponding pixel gray value can be expressed as

$$t_{di} = \omega_y d_{bi} + \omega_d d_{bi} \quad i = 1, 2$$

(5)

where $d_{bi}$ and $d_{bi}$ indicates the distance between the central gray value point to the target gray value point and the background gray value point, respectively.

The smaller the distance between each pixel and various categories centers of background category and target category, the better the cohesion of the pixels in various categories, so it can use $t_{di}$ to measure the quality of each cohesion, the smaller the $t_{di}$ and the more uniform the pixel between categories are, the better the cohesion is, so the better the image segmentation results is.

To obtain the best image segmentation result, it is necessary not only to ensure the maximum distance between the categories, but also to ensure the best cohesion of each category. That is to say, $\delta_i$ must be the biggest and $t_{di}$ must be the smallest.

Considering Eq. (4) and (5) together, a new threshold identification function is constructed as follows

$$\phi_i = \frac{\omega_y (1-\omega_d) \delta_i}{t_{di}} \quad i = 1, 2$$

(6)

where $1-\omega_y = \omega_d$.

The maximum value of $\phi_i$ can be obtained by comprehensive considering the minimum value of $t_{di}$ and maximum value of $\delta_i$ in the Eq. (6), and a maximum threshold value can be obtained, so it is the most likely to achieve the consistency in each category, and to achieve the maximum separation between categories.

2.2. Improved Canny edge detection operator

In the image edge detection, Canny edge detection operator is a very common edge detection optimization operator [8].

When the first order partial derivative finite difference method is used to calculate the gradient amplitude and direction of each point in the image after smoothing by Gaussian, the corresponding gradient amplitude image and gradient direction image can be obtained.

The two partial differentials of point $(i, j)$ along the direction of x axis and y axis can be shown as follows

$$\begin{cases}
G_x(i, j) = \frac{f(i, j+1) - f(i, j) + f(i+1, j+1) - f(i+1, j)}{2} \\
G_y(i, j) = \frac{f(i, j) - f(i, j+1) + f(i+1, j) - f(i+1, j+1)}{2}
\end{cases}$$

(7)

Gradient amplitude value $G(i, j)$ and gradient direction value $\theta(i, j)$ of point $(i, j)$ along x axis and y axis can be obtained by average finite difference calculation of neighborhood matrix, which is shown as follows.
\[
\begin{align*}
G(i, j) &= \sqrt{G_x^2(i, j) + G_y^2(i, j)} \\
\theta(i, j) &= \arctan \left( \frac{G_y(i, j)}{G_x(i, j)} \right)
\end{align*}
\]

(8)

However, in the gradient calculation of Eq. (8), some important edge information will be lost, especially some of which on the declining edge, so we can again extract the gradient of two inclined directions to increase some abundant information.

The two deviations of point \((i, j)\) along the x axis with 45° and 135° can be expressed as

\[
\begin{align*}
G_x'(i, j) &= f(i, j - 1) + 2f(i + 1, j - 1) - f(i - 1, j) + f(i + 1, j) - 2f(i - 1, j + 1) - f(i, j + 1) \\
G_y'(i, j) &= -2f(i - 1, j + 1) - f(i, j - 1) - f(i - 1, j) + f(i + 1, j) + f(i, j + 1) + 2f(i + 1, j + 1)
\end{align*}
\]

(9)

The corresponding gradient amplitude \(G(i, j)\) and gradient direction \(\theta(i, j)\) can be obtained as

\[
\begin{align*}
G'(i, j) &= \sqrt{G_x'^2(i, j) + G_y'^2(i, j)} \\
\theta'(i, j) &= \arctan \left( \frac{G_y'(i, j)}{G_x'(i, j)} \right)
\end{align*}
\]

(10)

The maximum value of the Eq. (10) is taken as the final gradient amplitude by finally comparing. The gradient direction can be expressed as

\[
\begin{align*}
G_M(i, j) &= \max \{ G(i, j), G'(i, j) \} \\
\theta_M(i, j) &= \max \{ \theta(i, j), \theta'(i, j) \}
\end{align*}
\]

(11)

In order to determine the edge, the non maxima restrain is actualized by gradient amplitude, and the double threshold algorithm [9] is used to connect the edge to extract the image edge information.

It can be further refined, which has more accurate positioning, as close to the real edge as possible, so as to get more precise edge information.

2.3. Edge information extraction based on mixd method

In order to obtain clear edge information of the noisy and fuzzy PCB photoelectric image, we can combine the method of median filter, IMDBC and ICEDO to actualize those processing of image segmentation and edge information extraction.

The median filter has a good ability to smooth the noise. Firstly, the noise from the PCB photoelectric image is removed preliminarily by using this filter. Then the edge fuzziness is removed by appropriate image enhancement processing. Lastly, we can convert color image to gray image.

The IMDBC can better obtain a maximum threshold \(\phi_i\). It is the most likely to achieve the consistency between categories to achieve the maximum separation between categories. Then the IMDBC is used to gray image \(f(x, y)\) to actualize threshold segmentation, and the target information of such image is segmented preliminarily. However, there are a lot of interference points or other irrelevant information in the segmented image.

The ICEDO can extract integrally the edge information that includes the pixel point \(f(i, j)\) of the target image, and the final image with higher accuracy edge information is obtained.
3. Experimental results and analysis

In the process of image acquisition, the PCB photoelectric image will inevitably contain noise and fuzziness phenomenon due to the influence of illumination equipment, surrounding environment and signal transmission. Therefore, it is difficult to extract the edge information of such image with a single edge information extraction method, and it is difficult to restrain the noise and eliminate the fuzziness phenomenon.

In order to better extract the edge information of such image that contains Gauss noise and fuzziness, we use a mixed method based on IMDBC and ICEDO to actualize an experiment.

Such noisy and fuzzy image acquired by charge coupled device (CCD) imaging system is shown as Figure 1(a). The de-noising processing is used to the original image by the median filter, and the target information of the image is extracted by the IMDBC, as shown in Figure 1(b). The ICEDO is used to extract the edge information of Figure 1(a), and the edge information image obtained as shown in Figure 1(c). In this paper, the ICEDO is used to extract the edge information of Figure 1(b), and the edge information image obtained as shown in Figure 1(d).

![Figure 1. Edge information extraction results of noisy and fuzzy PCB photoelectric image acquired by CCD](image)

(a) Original noisy and fuzzy PCB photoelectric image  
(b) Extracted target information by IMDBC  
(c) Result by ICEDO aiming at Figur 1(a)  
(d) Result by our method

The image which includes the Gauss noise and the fuzziness obtained by the microscope as shown in Figure 2(a), the Figure 2(b), (c) and (d) are the corresponding processing results images, respectively.
It can be seen from the experiment results of Figure 1 and 2 that it is difficult to extract the edge information of the images only by using the ICEDO, but our method mentioned in this paper can better extract their edge information. Especially in the location with more fuzziness and noise points, our method works better. Because they are the advantages combination of the IMDBC and the ICEDO.

In order to objectively evaluate the results of image edge information extraction, the excellent quality coefficient $P_i$ is used as the evaluation index of edge information extraction performance [2].

$$P_i = \frac{1}{\max\{n_o, n_d\}} \sum_{i=1}^{n_e} \frac{1}{1 + \hat{\delta} d_i^2}$$

(12)

where $n_o$ and $n_d$ represent the ideal and real points extracted from the image edge, respectively. $\hat{\delta}$ is the proportion coefficient use to adjust $P_i$ that have the deviation from the ideal edge point, $d_i$ is the normal distance that from the actually extracted ith edge point to the ideal edge line, and its unit is pixel.
Supposing that $\beta = 0.1$, we extract the edge information of original image as shown in Figure 1(a) and 2(a) by using the ICEDO. aim at original image (IAOI), literature [2] method, literature [3] method and our method, respectively. The experimental results of excellent quality coefficient $P_i$ of corresponding methods are shown in Table 1.

Table 1. Image excellent quality coefficients by using different edge information extraction methods

|       | IAOI   | Literature [2] method | Literature [3] method | Our method |
|-------|--------|------------------------|------------------------|------------|
| Figure 1 | 0.7480 | 0.7987                 | 0.8014                 | 0.8346     |
| Figure 2 | 0.7069 | 0.7557                 | 0.7687                 | 0.7981     |

The comparison of time taken by various edge information extraction methods is shown in Table 2.

Table 2. Comparison of time in different edge information extraction methods (Unit: s)

|       | IAOI   | Literature [2] method | Literature [3] method | Our method |
|-------|--------|------------------------|------------------------|------------|
| Figure 1 | 0.3412 | 0.3173                | 0.3416                 | 0.1824     |
| Figure 2 | 0.4262 | 0.3931                | 0.4158                 | 0.2159     |

Seen from these data listed in Table 1 and 2 that our method is the best of these methods that be used, because it is the comprehensive utilization of median filtering, the IMDBC and the ICEDO, it focuses on the advantages of each other's methods, and it has relatively higher quality coefficient. It can be seen that the proposed method can better extract the edge information of such images.

3 Conclusion

According to the actual condition and difficulties of noisy and fuzzy PCB photoelectric image edge information extraction, a mixed method by combining median filtering, IMDBC as well as the ICEDO is adopted in this paper. Firstly, the noisy and fuzzy images preprocessing is carried out by median filter. Secondly, the images target segmentation information is obtained by using the IMDBC. Finally, aiming at the images target segmentation information, the clearer and preciser edge information is extracted by the ICEDO.

Acknowledgement

We are grateful for the support from the National Natural Science Foundation of China (61701050, 61703157), Applied Characteristic Subject of Hunan Province “Electronic Science and Technology” and the Hunan Province Key Laboratory of Photoelectric Information Integration and Optical Manu - Facturing Technology and the Open Foundation of State Key Laboratory of Electronic Thin Films and Integrated Devices (KFJJ201807), the Foundation of Hunan Educational Committee, China (18A360), and 2020 Changde Science and Technology Innovation Development Project (2020S095).

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