Orientation holes positioning of printed board based on LS-Power spectrum density algorithm

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ABSTRACT. *With ROI can not obtained easily under uneven illumination ,the purpose of this study was to solve the the problem of low precision and slow speed when orientation holes positioning is performed manually. A novel hybrid extraction method in frequency domain(LS- Power Density Algorithm)was adopted in this paper. The results indicated that the region of interest (ROI) can be obtained easily with help of Canny operator and Otsu algorithm in image prepossessing technology. Furthermore,in the context of PCB images with background noise and uneven illumination, LS- power density algorithm play an important role on punching recognition and the orientation holes positioning of printed board.Moreover, compared with the existing orientation positioning techniques(k-means , LMS and SVM), the improved algorithm can reach a good result. At last the performance of LS-PSD is carefully evaluated by simulation in MATLAB.And the findings of this study may serve as electronic information process of mobile industry.*

RÉSUMÉ. *Du fait que la région d'intérêt ne peut pas être obtenu facilement sous un éclairage inégal, le but de cette étude était de résoudre le problème de la faible précision et de la vitesse lente lorsque le positionnement des trous d'orientation est effectué manuellement. Une nouvelle méthode d'extraction hybride dans le domaine fréquentiel (l'algorithme de densité spectrale de puissance LS) a été adoptée dans cet article. Les résultats ont indiqué que la région d'intérêt (ROI en anglais) peut être obtenue facilement à l'aide de l'opérateur Canny et de l'algorithme Otsu par la technologie de prétraitement d'image. De plus, dans le contexte des images de circuit imprimé avec le bruit de fond et l'éclairage inégal, l'algorithme de densité spectrale de puissance LS joue un rôle important dans la reconnaissance de poinçonnage et le positionnement des trous d'orientation du circuit imprimé. En outre, par rapport aux techniques de positionnement d'orientation existantes tels que Les k-moyennes, LMS et SVM,*

l'algorithme amélioré peut réaliser un bon résultat. Enfin, les performances de l'algorithme de densité spectrale de puissance LS sont attentivement évaluées par simulation Matrix Laboratory (Matlab en anglais). Et les résultats de cette étude peuvent également servir de processus d'information électronique pour l'industrie mobile.

1. Introduction

With the rapid development of the electronic information industry., cameras and smart-phones, and the growing demands on "more holes, smaller pore diameter and shorter line spacing" in designated area of PCB, the products manufacturing industry of electronic information pay much more attentions on identifying the Region of Interest of the PCB printed board. Obviously, this task is of great challenge to product manufactures. To deal with the problem, orientation positioning techniques has been proposed and receives growing attention in the recent years (Shen *et al.*, 2016; Zhang *et al.*, 2015; Liu *et al.*, 2015; Sanchez and Hernandez-Cabronero, 2018; Zhang *et al.*, 2017).

However, in practice, the image groups are achieved under complex settings and scenarios, such as diverse backgrounds, poor or illumination conditions and photo point variations. The main aim of the orientation positioning techniques task is to get the interesting information, i. e., the common and special shape with fixed dimension from a group images weakly prepossessing as contained with similar features, while this work is evidently more challenging while the orientation positioning in real applications, such as k-means, LMS and SVM methods are studies in recent years (Santosh *et al.*, 2016; Kuang *et al.*, 2016; Joshi *et al.*, 2016; Zandi *et al.*, 2016; Qian *et al.*, 2017).

With the repaid development of electronic industry, high precision and fast speed of ROI detection are demanded nowadays. For solving the problem, we make the effort to clarify a natural relationship between gray image, Otsu image processing and image equalizing. So, a novel hybrid extraction method in frequency domain (LS-Power Density Algorithm) was adopted in this paper. With the help of initial extraction, the hybrid extraction is hopeful to deal with the problem of orientation different types holes positioning of PCB.

The rest of this paper is organized as follow, the PSD filter is introduced in Section 2. And Section 3 is focus on bottom-up strategy. Simulation and analysis are studied in Section 4. The conclusions are drawn in Section 5.

2. LS-Power spectrum density ROI detection

A novel method，aiming at Via -holes ROI detection, is introduced hereafter. Compared most Power Spectrum Density (PSD), the convergence rate of the ROI detection should be improved. Some researchers pay much more attention on the complex features such as edge and intensity (Santosh *et al*., 2016; Kuang *et al*., 2016; Joshi *et al*., 2016; Zandi *et al*., 2016; Qian *et al*., 2017; Ur-Rehman and Zivic, 2017; Roth *et al*., 2016). However, most detection algorithms in PCB images are based on task-driven strategy, moreover the complex features are made up by linear combination of two or three indexes (Itti *et al*., 1998; Harel *et al*., 2007; Hou and Zhang, 2007; Cheng *et al*., 2011; Li and Itti, 2011; Cui *et al*., 2017; Loog and Lauze, 2010; Li *et al*., 2016; Tao *et al*., 2013; Sebe, 2001) (such as $\alpha = k_1\beta_1 + k_2\beta_2 (where\ k_1 + k_2 = 1)$),so the convergence rate may become more and more slower as the detection features grows larger.

On the other hand, some researchers also considered the characteristics in frequency domain to compute the salient map (Zhang *et al*., 2016; Carson *et al*., 2002). Furthermore, some hybrid strategy is also proposed (Carson *et al*., 2002; Shi *et al*., 2015; Zhang *et al*., 2014).Compared with serial strategy, the hybrid strategy can deal with more throughout of image data at set time. Therefore, to located Via -holes ROI detection in Printed Board, a hybrid ROI detection method is proposed in this paper.The proposed LS- power spectrum density ROI detection method (LS-PSD) is made up by bottom-up and top-down strategies. The schematic of the LS-PSD is shown in Figure 1.
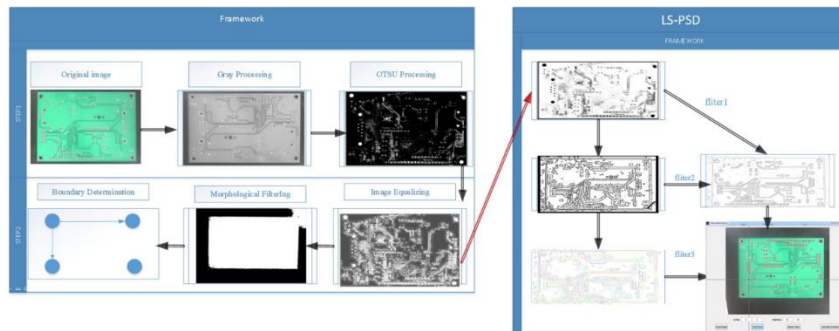

Figure 1. Framework of LS- power spectrum density ROI detection method (LS-PSD), which can be divided into two parts:(LEFT) Initial extraction ;(RIGHT) Refine extraction

In this section, besides reviewing power spectrum density (PSD), some useful properties are introduced. AR model, MA model and ARMA model are three mixed linear model, and the ARMA model is the combination of MA model and AR model. And the difference equations of ARMA (p,q)are shown as following :

$$\sum_{k=0}^{p} a_k x(n-k) = \sum_{k=0}^{q} b_k w(n-k)$$

$$(1)$$

Where $w = \sum_{j=1}^{k} \alpha_j \varphi(x_j)$ For simplicity, one can choose $\varphi(x) = K(\bullet, x)$.then the output classification function is

$$f(x) = \sum_{j=1}^{k} \alpha_j K(x_i, x) + b$$

$$(2)$$

Then the transfer function of ARMA is

$$H(z) = \frac{1 + b_1 z^{-1} + b_2 z^{-2} + \cdots + b_q z^{-q}}{1 + a_1 z^{-1} + a_2 z^{-2} + \cdots + a_p z^{-p}}$$

$$(3)$$

Where r(l) is auto-correlation coefficient, then

$$r_x(l) = \begin{cases} -\sum_{k=1}^{p} a_k r_x(l-k) + \sigma_w^2 \sum_{k=l}^{q} b_k h(k-l) & 0 \le l \le q \\ -\sum_{k=1}^{p} a_k r_x(l-k) & l \ge q \end{cases}$$

$$(4)$$

Then the power spectrum density (PSD)of the unite system is

$$s_x(w) = \sigma_w^2 \left| \frac{1 + \sum_{k=1}^{q} b_k z^{-k}}{1 + \sum_{k=1}^{p} a_k z^{-k}} \right| = \sigma_w^2 \left| \frac{\prod_{k=1}^{q}(1 - z_k z^{-1})}{\prod_{k=1}^{p}(1 - p_k z^{-1})} \right|^2_{z=e^{jw}}$$

$$(5)$$

As can be shown in equation (6), the frequency of PD and the maximum PD value can be calculated by the different window's spectral density functions (such as Boxcar data sampling, Hamming data sampling and Black-man data sampling etc.).

$$\int_{-\infty}^{+\infty} |s(t)|^2 dt = \int_{-\infty}^{+\infty} |S(f)|^2 df$$

$$(6)$$

3. Initial ROI extraction

In order to have a good and fast pattern recognition result on the classification between gray image, otsu image processing and image equalizing. There are two

bottom-up parts in the ROI pattern recognition: data-training stage and data-testing stage. The flow chart based on initial ROI extraction algorithm is shown in Figure 2.
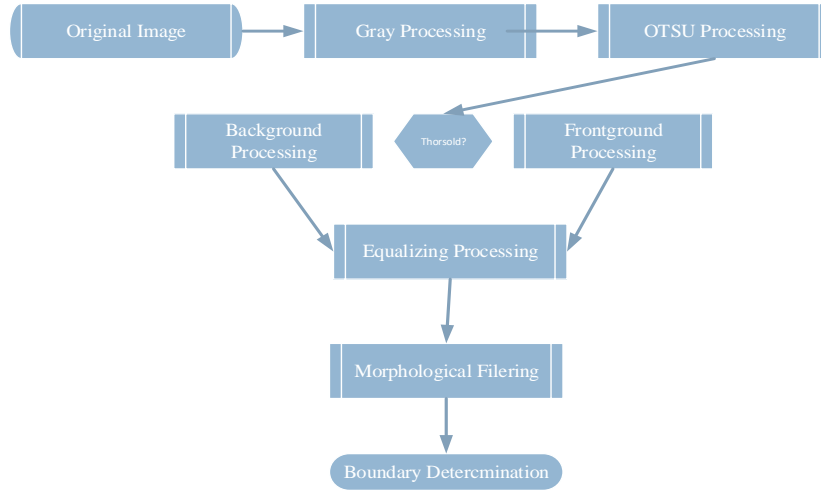

Figure 2. Flow chart based on initial ROI extraction algorithm

3.1. OTSU Image Processing

Suppose *i* is threshold of image segmentation, the whole image can be divided into two parts Background parts (BP) and Foreground parts (SP). The region area of BP and SP is θ_1, θ_2:

$$\theta_1 = \sum_{j=0}^{i} \frac{n_j}{n}; \theta_2 = \sum_{j=i+1}^{G-1} \frac{n_j}{n} \tag{7}$$

where G is the gray degree of the whole image.

Furthermore, the average gray degree of the whole image, Background parts (BP)and Foreground parts (FP) is μ, μ_1, μ_2:

$$\mu = \sum_{j=0}^{G-1} (f_j \times \frac{n_j}{n}) \tag{8}$$

$$\mu_1 = \frac{1}{\theta_1} \sum_{j=0}^{i} (f_j \times \frac{n_j}{n}) \tag{9}$$

$$\mu_2 = \frac{1}{\theta_2} \sum_{j=i}^{G-1} (f_j \times \frac{n_j}{n})$$

(10)

Where $\mu = \mu_1\theta_1 + \mu_2\theta_2$

With help of OTSU image processing, the binary image can be obtained as shown in Figure 3.
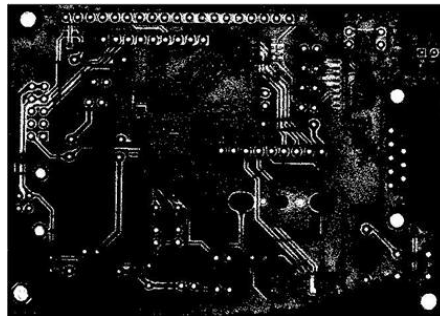

Figure 3. The binary image with OTSU image processing

3.2. Image equalizing and morphological filtering

In the method of LS-SPD, there are three parameters needed to be fixed: the scanning step S, the threshold of maximum value of Via holes X, and the threshold of the voting image Z. In order to obtain the three parameters, three different filtering are designed in different structures.
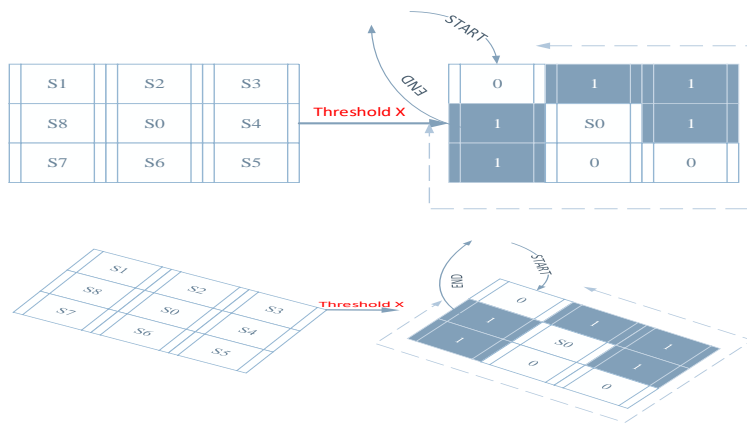

Figure 4. The Features and structure used in detection

Firstly, the threshold of the voting image Z plays an important role in image ROI extraction. The feature and the structure used in detection is shown in Figure 4

With the help of morphological filtering (that is Filter1), the centered distribution map (CDM) is generated by assigning value, which can be located the centered point and can be represented as

$$CDM\,(i,\,j) = \begin{cases} 1, i = \overline{x_k}, j = \overline{y_k} \\ \quad 0, else \end{cases} \tag{11}$$

The centroid distance of distribution indention (CDDI) is defined as:

$$CDDI = Te_{n \times n} \otimes CDM \tag{12}$$

Where The is the unit template.

Secondly, the threshold of maximum value of Via holes X can be obtained by PSD filtering (that is Filter2), which can scan across the image at multiple and locations. The feature used PSD in detection is shown in Figure 5.
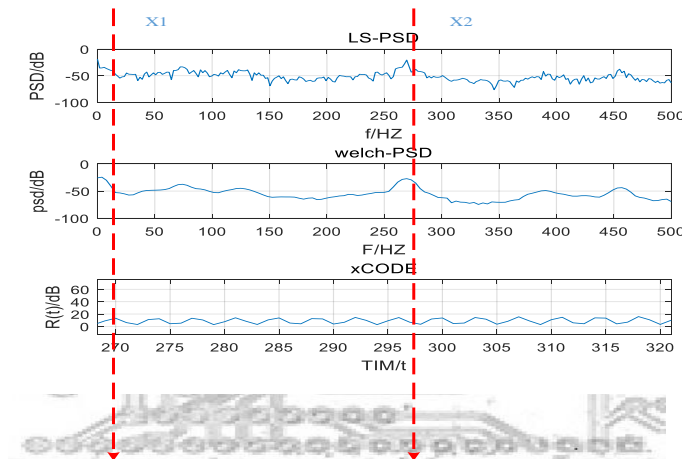

Figure 5. The Features detection used in LS-PSD

As can be seen from Fig.5, the welch number and the LS-PSD number become high when the number of Via holes of PCB becomes double in number. With the help of numerical fitting tool, the X can defined as equation (13), when the X<0.001, then the number of Via poles should be changed.

$$X = k_1 \frac{d_{LS-PSD}}{dt} + k_2 \frac{d_{weltch-PSD}}{dt} \tag{13}$$

4. Experimental results

With help of MATLAB 2015a, Fig.6 shows the ROI detection results by the proposed method. Having extracted the Via -holes of PCB in general. And the results show that the proposed LS-PSD algorithm can not only suitable for punching recognition of the circuit board, but also the he orientation holes positioning of printed board as well. Comparisons of precision of K-MEANS, LS-PSD and SVM are shown in Fig.7.On the other hand, the Orientation Holes Positioning identification results and Via holes ROI detection pattern are displayed in TABLE 1. And pattern recognition results by LMS, K-means and LMS algorithm with the same computer (with CPU of 2GHz) are also shown in TABLE 2. TABLE 1 Results of pattern recognition by LS-PSD algorithm.

It can be seen the proposed LS-PSD algorithm obtained the highest P, R and F values, and the best performance of results can be achieved compared with the other two algorithms (SVM AND K-MEANS). As can be seen from TABLE 1 and TABLE 2, compared with the K-mans, LMS and SVM, LS-PSD algorithm can improve the accuracy (from 75.3%,85.2%,92.5% to 96.9%). As for the ROI detection on the orientation holes positioning of printed board. Moreover, in the context of PCB images with background noise and uneven illumination, the proposed method can achieve good results.
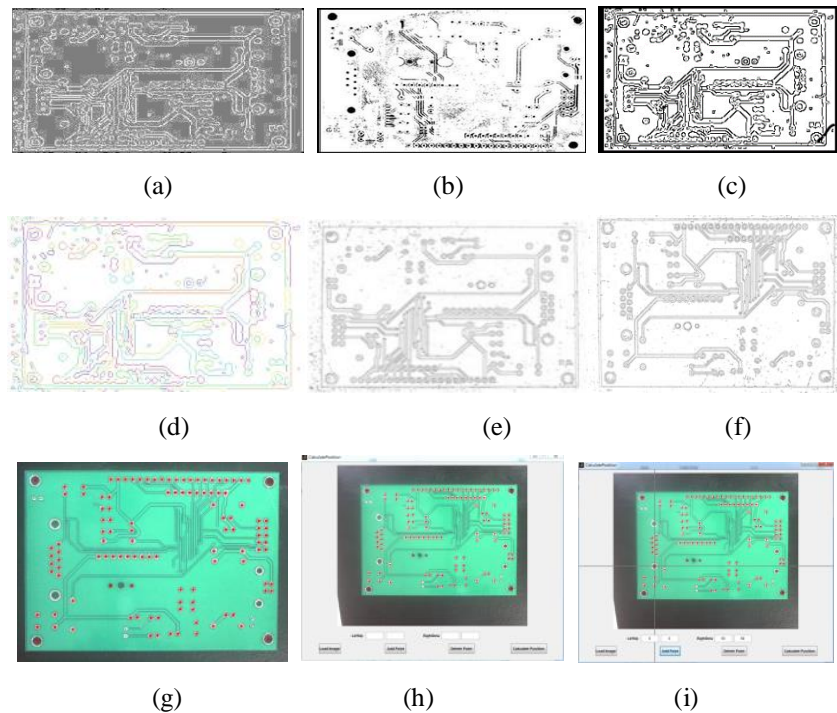

(a)	(b)	(c)
(d)	(e)	(f)
(g)	(h)	(i)

Figure 6. ROI detection based on different step of proposed algorithm

(a) and (b) original image; (c) and (d) CDM model; (e) and (f) PSD model (g,h,i) LS-PSD model
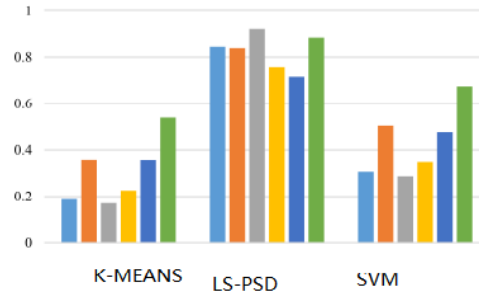

Figure 7. Comparisons of precision of K-MEANS, LS-PSD and SVM

Table 1. Results of pattern recognition by LS-PSD algorithm

POLES types	Results of pattern recognition			correct rate
	L	M	S	
Large holes	50	2	2	92.6%
Middle ogles	2	49	3	90.7%
Small holes	3	2	49	90.7%
Average				96.9%

Table 2. Results of ROI detection by k-means, LMS and SVM algorithm

POLES-types	Results of pattern recognition			correct rate	Results of pattern recognition			correct rate	Results of pattern recognition			correct rate
	K-MEANS				LMS				SVM-RBF			
	L	M	S		L	M	S		L	M	S	
Large holes	40	7	7	74.1%	45	5	4	83.3%	48	3	3	88.9%
Middle holes	10	37	7	68.5%	3	45	6	83.3%	3	48	3	88.9%
Small holes	2	7	45	83.3%	3	3	48	88.9%	2	2	50	88.9%
Average			75.3%				85.2%				92.5%

5. Conclusion

In this paper, the hybrid strategy is also proposed with three filtering (CDDI, OTSU and PSD), and the proposed method with two bottom-up and top-down strategies. Different types of ROI are considered by CDDI and centred distribution map (CDM), which do good to the location of the centred point of PCB. At last the LS -PSD method can scan across the image at multiple and locations, and the maximum radius of the Via circle on PCB.And the simulation results also demonstrate the effectiveness of the improved method. On the other hand, the LS-PSD method can meet the requirements of comprehensive punching recognition of the circuit board.

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