ATLANTIS PRESS
Advances in Computer Science Research, volume 92
International Conference on Mathematics, Big Data Analysis and Simulation and Modeling (MBDASM 2019)

The SMT Solder Joint Quality Inspection Based on Image Surface Visual Restoration

Nan Yu[1,*] and Jing Zhang[2]
[1]School of Information Engineering, Da Lian University, Da Lian 116622, China
[2]School of Physics and Materials Engineering, Dalian Nationalities University, Dalian 116600, China
*Corresponding author

***Abstract*—The emergence of surface mount technology (SMT) has created new challenges. The most challenging is the need for more capable system to monitor the product quality. Currently, the most popular method is based on machine vision for automated optical inspection (AOI). But they generally only work in 2D testing mode, cannot make a more objective assessment for solder joints. This paper describes a three-dimensional (3D) inspection system based on recovery of the surface of solder joints.**

Contents include four parts: combinate wavelet packet image denoising, and different filtering methods, the mixed denoising method of SMT solder joint image is studied; the 3D illumination model suitable for SMT solder joint reconstruction is presented; based on SFS technology, the 3D reconstruction technology of solder joint was studied; the 3D solid model and morphological parameters of solder joint were obtained.

This paper resolved the problem of SMT solder joint 3D quality information automatic extraction. The results can provide 3D quality information for SMT solder joint quality comparison, analysis and intelligence discrimination of solder joint quality.

Keywords*—SMT solder joint; illumination model; shape from shading; three-dimensional quality information

I. INTRODUCTION

The application of Surface Mount Technology (SMT) has opened a broad prospect for the miniaturization, thinness and lightness of electronic products. The PCB electronic circuit products formed by SMT have the advantages of small volume, light weight and high integration. However, the reliability problem is more and more prominent. In practice, information can be obtained from SMT solder joint images to test the quality of SMT solder joint and circuit reliability.

Currently, the SMT solder joint quality inspection technology is mostly 2D detection method, through 2D image processing for solder joint quality detection. It is difficult to sample and detect the characteristics of solder joints due to the influence of angle and lighting. In order to overcome the shortcomings of 2D solder joint quality inspection, depth coordinate information is added, and 3D solder joint quality inspection is proposed. Accurate 3D solder joint detection overcomes the shortcomings of sensitivity to light and angle in 2D solder joint detection [1].

Therefore, this paper utilizes image grayscale information to reconstruct the Shape from Shading (SFS) of SMT solder joint through a single image, to complete the 3D quality inspection of the solder joint. The research contents of this paper include: based on the wavelet packet image denoising theory, combined with the different filtering methods, research on SMT solder joint image mixed denoising method; based on the light model theory, the illumination model of SMT solder joint 3D reconstruction is studied; based on SFS technology, the improved illumination model was used to study the solder joint 3D reconstruction technology; the 3D solid model of the solder joint was obtained, and the morphological parameters reflecting the 3D quality of the solder joint were extracted. Fig.1 is the overall research idea of the above ideas.

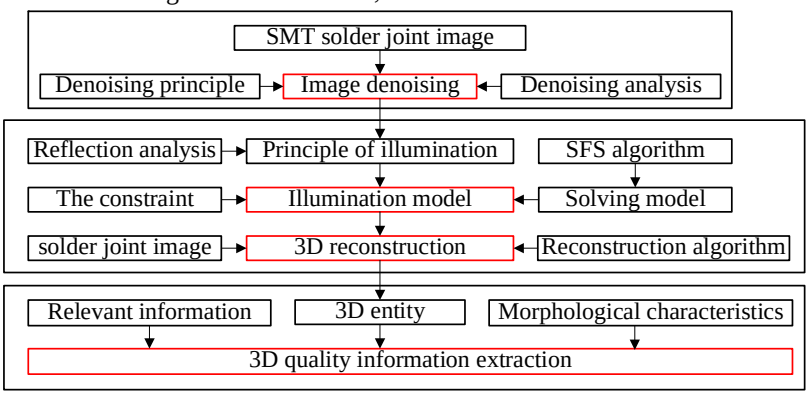


FIGURE I. RESEARCH IDEA OF SOLDER JOINT IMAGE PROCESSING AND 3D QUALITY INFORMATION EXTRACTION

Copyright © 2019, the Authors. Published by Atlantis Press.
This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/).

II. Analysis of SMT Solder Joint Image Mixed Denoise Technique

In the processing of SMT solder joint images, different noises are mixed, including salt-pepper noise and gaussian noise, which brings difficulties to SMT solder joint Inspection.

Most of the existing denoising methods are aimed at single noise removal. In this paper, combined wavelet packet adaptive (AWP) threshold calculation method, Wiener filter is selected as linear filter; Median filter is selected to smooth the image. The SMT solder joint image mixed denoising method based on AWPWM is studied.

A. *Wavelet Packet Adaptive Threshold Calculation Method*

The wavelet packet adaptive threshold (AWP) processing method is as follows [2, 3]:

(1) Calculating the variance of wavelet packet coefficient in the high-frequency part of wavelet packet decomposition;

(2) Arranging the absolute value of variance of wavelet packet coefficient in descending;

(3) According to the result of (2), the median value and wavelet packet coefficient are obtained;

(4) According to the results of (1), the optimal threshold position corresponding to the high-frequency coefficient is calculated and the optimal threshold value is obtained.

B. *SMT Solder Joint Image Mixed Denoising Algorithm*

Combined with AWP denoising algorithm, Wiener filtering and Median filtering, the SMT solder joint image mixed denoising algorithm is designed. The process is as follows:

(1) Selecting the largest layer number of wavelet packet decomposition, and wavelet packet decomposition is carried out to obtain the wavelet packet coefficients of each layer;

(2) Using Wiener filtering method to filter the wavelet packet coefficients of images;

(3) Calculating the absolute value of variance and arrange it in descending order to get the median value and wavelet packet coefficient;

(4) According to the AWP threshold calculation method, the optimal threshold value is calculated;

(5) The AWP threshold denoising method is adopted to carry out the second denoising;

(6) Reconstructing wavelet packet coefficient;

(7) Median filter is used for smoothing to get the denoised image.

C. *Denoising Results of SMT Solder Joint Images*

The SMT solder joint image shown in Fig. 2(a), the proposed AWPWM method is used to denoise. The window size of Median filter is 3 by 3, and the wavelet packet transform adopts 3-layer decomposition. The result is shown in Fig. 2(b).

(A) SMT SOLDER JOINT IMAGE

(B) 3 LAYERS OF DECOMPOSITION AND MEDIAN FILTER 3 BY 3

FIGURE II. THE DENOISING RESULT OF STM SOLDER JOINT IMAGE

By comparison with Fig.2 (a) and Fig.2 (b), it can be concluded that the noise of solder joints in Fig.2 (a) has been basically eliminated, and edge information is well preserved.

III. SMT Solder Joint Surface Illumination Model

A. *The Surface Light Reflection Analysis of SMT Solder Joints*

The SMT solder joint and its image have the following characteristics:

(1) SMT solder joint is non-transparent body and will not produce transmitted light;

(2) The influence of ambient light on solder joint images is small, which can be ignored;

(3) The light source direction is the same as the shooting direction, and the diffuse reflection component is the basic term;

(4) The surface of SMT solder joint is relatively smooth, the specular reflection component cannot be ignored.

SMT solder joint surface illumination model is consisted of diffuse and specular reflection term.

B. *Diffuse Reflection Model and Improvement*

Commonly, the diffuse reflection models include Lambert model and Oren-Nayar model [4].

Lambert model is not considering the effect of observation direction on reflection results, and can only approximately descript light reflection phenomenon. Oren and Nayar proposed a new model, but its mathematical expression was complex and could not be used in SFS algorithm to reconstruct SMT solder joint 3D images.

The Oren-Nayar illumination model considers the mutual reflection of light, but the surface of SMT solder joint is smooth, so the contribution of the mutual reflection to the grayscale information of solder joint image is small, and it has little impact on reconstruction accuracy. Therefore, the mutual reflection of the Oren-Nayar illumination model can be ignored to obtain a simplified illumination diffuse reflection model.

C. *Specular Reflection Model and Improvement*

The mathematical expression of the conventional specular reflection model is difficult to apply to the inverse calculation of nonlinear partial differential equations. Torrance-Sparrow puts forward a simple illumination specular reflection model. Assuming, slope distribution function of surface micro plane

conforms to the gaussian distribution, the surface of the illuminated object is composed of numerous tiny plane mirrors, and the simplified specular reflection illumination intensity is obtained. The simplified illumination specular reflection model can simulate the illumination specular reflection model.

D. *Illumination Model Analysis of SMT Solder Joint Surface*

Based on the above analysis of the SMT solder joint surface illumination model, the improved illumination model can be written as follows:

(1) The illumination model of solder joint image contains two components: diffuse reflection component and specular reflection component;

(2) Improve the Oren-Nayar diffuse reflection model, eliminate the mutual reflection component;

(3) Improve the specular reflection model, simplify mathematical expression;

(4) The improved illumination model is obtained by linear superposition of specular reflection component and diffuse reflection component.

IV. Research on 3D Reconstruction Algorithm Based on Improved Illumination Model

The improved illumination model is used to reconstruct the 3D surface of objects, so SFS method must be used to solve the illumination model [5-8]. The gradient direction of the object surface is calculated by using the image grayscale, and then the surface height of the object is solved iteratively by the surface gradient direction.

In this paper, linear method is used to solve the improved illumination model. Taking surface gradient as variable, use finite difference method to discretization, and then use Jacobi iterative method to solve.

A. *Algorithm Flow of Surface 3D Reconstruction Based on SFS Technology*

Combined with the improved lighting model, a single image reconstruction SMT solder joint surface 3D shape algorithm based on SFS technology is designed, and the flow is shown in Fig. 3. In Fig. 3, the discretization expression is the solution result expression of SFS method for improved illumination model, and reconstruction result is highly discrete matrix of solder joint surface.

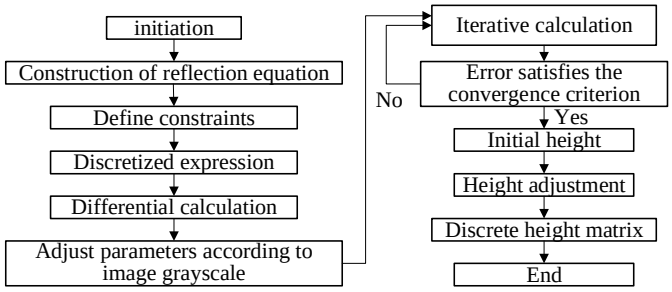
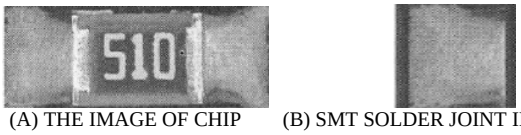


FIGURE III. THE FLOW OF 3D SHAPE ALGORITHM OF SOLDER JOINT SURFACE RECONSTRUCTION BASED ON SFS METHOD

B. *Results of 3D Shape Reconstruction of Solder Joint Surface of SMT Chip*

The image of chip is shown in Fig. 4(a), and the left solder joint as shown in Fig. 4(b).



(A) THE IMAGE OF CHIP (B) SMT SOLDER JOINT IMAGE

FIGURE IV. THE IMAGE OF CHIP AND SOLDER JOINT

Using AWPWM denoising algorithm, and then reconstructing surface 3D shape of SMT solder joint based on SFS. The result is shown in Fig. 5.

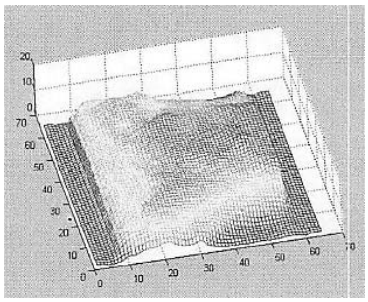


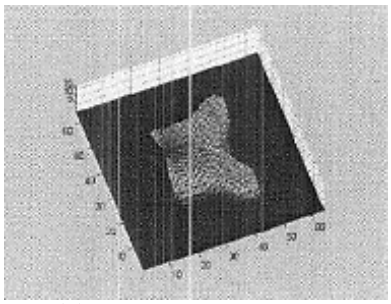
FIGURE V. THE RESULT OF SOLDER JOINT SURFACE RECONSTRUCTION BASED ON IMPROVED ILLUMINATION MODEL

V. 3D Quality Information Extraction of SMT Solder Joint

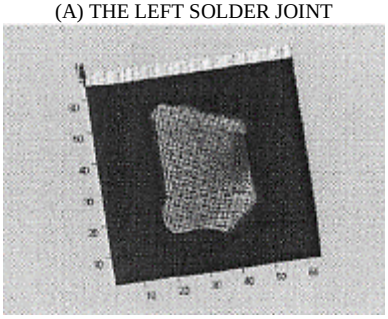
A 3D solid model of SMT solder joints was established through height matrix, and 3D quality information of SMT solder joints was extracted, including: solder joint volume, profile information, and wetting angle.

This research method is used to extract the quality information of resistance solder joints. The test image is shown in Fig.6. The solid model of solder joint is shown in Fig.7. The 3D quality information and accuracy are shown in Tab.1.

FIGURE VI. IMAGE OF CHIP RESISTANCE SOLDER JOINT



(A) THE LEFT SOLDER JOINT



(B)THE RIGHT SOLDER JOINT

FIGURE VII. SOLID MODEL RECONSTRUCTION OF CHIP RESISTANCE SOLDER JOINTS

TABLE I. THE RESULT OF 3D QUALITY INFORMATION EXTRACTION OF RESISTANCE SOLDER JOINTS

solder joints	left solder joint	right solder joint
profile information（pix2）	168.3	280.5
wetting angle（°）	15.82	31.05
actual volume（mm^3）	0.0955	0.1653
reconstruction volume（mm^3）	0.0852	0.1504
volume reconstruction accuracy	0.892	0.9098

VI. CONCLUSION

In this paper, 3D reconstruction of SMT solder joint surface and quality information extraction technology are studied, the main contents include:

1) Using the improved adaptive wavelet packet threshold calculation method, combined with Wiener filtering and Median filtering, the mixed denoising algorithm is studied to effectively remove the mixed noise in solder joint image;

2) Improving the diffuse reflection and specular reflection of the solder joint surface, and superimposing linearly to obtain the SMT solder joint surface illumination model;

3) Studying 3D reconstruction method of SMT solder joint surface based on SFS technology to realize 3D reconstruction of solder joint surface;

4) Studying 3D quality information extraction technology of SMT solder joint, and realizing the volume, middle profile and wetting angle extraction of SMT solder joint. The results show that the average accuracy of volume extraction is 90.09%.

ACKNOWLEDGMENT

This work was supported financially by Dalian High-level Talent Innovation support program (Project: No: 2017RQ038).

REFERENCES

[1] Huang Chunyue. Study on SMT Solder Joints Quality Inspection Discrimination Based on Solder Joint Virtual Evolving Technology[D], Dissertation, XIDIAN University, 2007.

[2] Chang, C.S., Jin, J., Kumar, S., Su, Q., Hoshino, T., Hanai, M., Kobayashi, N.. Denoising of Partial Discharge Signals in Wavelet Packets Domain[J]. IEEE Proc.-Sci. Meas. Technol,2005,152(3):129-134.

[3] Miller, Nick Kingsbury. Image Denoising Using Derotated Complex Wavelet Coefficients[J]. IEEE Trans Image Processing, 2008,17(9): 1500-1511.

[4] Tsunashima, H. Saito and N. Estimation of 3D Parametric Models from Shading Image Using Genetic Algorithms[C]. IEEE Computer Society Conference on Computer Vision and Pattern Recognition,1994:668-670.

[5] R.Zhang, P.-S. Tsai, J.E.Cryer and M.Shah. Shape from Shading: A Survey[J]. IEEE Trans, on Patern Analysis and Machine Intelligence (PAMI),1999,21(8):690-705.

[6] Kong Fanhui, Wang Yongxin. Reconstruction of Solder Joint Surface Based on Shape from Shading[C]. IEEE Third International Conference on Natural Computation,2007:58-62.

[7] Ahmed, A.H., Farag, A.A. A New Formulation for Shape from Shading for Non-Lambertian Surfaces[C]. 2006 IEEE Computer Society Conference on Computer Vision and Pattern Recognition,2006:1817-1824.

[8] GAO Yuefang, LUO Fei, and GAO Jianzhong. A Shape from Shading Algorithm and Its Application[C]. 2007 IEEE International Conference on Control and Automation, 2007:2133-2135.