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Image analysis of workpiece joints with uncertainty for cooperative feature constraints[1]

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Abstract. In order to improve the denoising effect of the solder joint image of the uncertainty workpiece, a new method of noise removal for the solder joint image based on the cooperative feature constraint and the radial singular function. The image is decomposed by the cooperative feature constraint through the analysis of the image characteristic constraint coefficient, and skews high-frequency part and the low-frequency part of the feature constraint coefficients. In order to improve the denoising performance, an improved self-adaptive eigenvalue algorithm is proposed by calculating the median absolute variance estimation corresponding to the characteristic coefficient, and the image is subjected to the second denoising. Finally, the median filter is used to smooth the image and get the final denoising image. The results show that compared with the traditional method, the proposed algorithm can not only improve the denoising performance and denoising effect, but also keep the uncertainty of the workpiece solder joint image edge information.

Key words. Uncertainty, workpiece solder joint, image denoising, cooperative feature constraint, radial singular function.

1. Introduction

In the case of uncertainty in workpiece image detection and recognition [1], due to the presence of noise of different properties in the image, the noise reduces the image quality, makes the image blurred, and sometimes submerges some of the effective features of the image, and brings difficulty on the analysis and research. Because of the existence of mixed noise in the solder joint, the traditional method is used to remove the uncertainty of the workpiece image denoising, the denoising effect is not ideal, and it is easy to destroy the edge information of the image. In many cases, salt and pepper noise and Gaussian noise or multiplicative noise at the same time there is uncertainty in the workpiece solder joint image [2]. The feature is a generalized

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concept of wavelet [3–4]. Feature analysis can provide a more sophisticated analysis of the signal because it not only divides the low frequency band into multiple levels but also for the multi-resolution analysis does not subdivision of the high-frequency part of the further decomposition. So the feature technology has a wider application value, has been applied to pattern recognition, image processing and many other areas [5–6]. The skewness filter is a classical linear smoothing filter and is a local adaptive linear filter based on the principle of minimum mean square error. It can adjust the output according to the local variance. The skew filter has a good denoising feature for the noise of the known noise distribution [7]. The Median filter is a nonlinear filtering technique which can effectively suppress the image noise and improve the image signal to noise ratio. Value filter can effectively filter out random noise and salt and pepper noise, while the image can be fine to retain the edge of the details. In order to improve the denoising performance, Wang [8] proposed a feature combined with median filtering algorithm (WPM) to improve the denoising performance to achieve a certain effect.

In this paper, the noise removal method of the workpiece is analyzed. The residual image of the workpiece is decomposed by the uncertainty of the workpiece, and the noise of the original image is estimated by the median absolute variance estimation method. By combining with the skewness filter and improving radial singular and median filter, it denoises the image at the same time protect the edge less subject to fuzzy.

2. Uncertainty workpiece contact point image removal algorithm based on cooperative feature constraint and radial singular function

2.1. Feature constraint system data skew filter

The image is decomposed into high frequency and low frequency parts. The image noise is mainly concentrated in the high frequency part, and the useful information of the image is mainly concentrated in the low frequency part. The high frequency part and partial low frequency part of the feature decomposition are filtered by using the skew filter to effectively remove the mixed noise in the image while preserving the edge and high frequency detail information of the image. For different levels of feature decomposition, the use of different window size of the skew filter, the characteristic coefficient skew filter process shown in Fig. 1.

2.2. Radial singular function denoising algorithm

The traditional feature threshold method is to keep the image coefficients and reduce most of the noise figure to zero. In practice, there are three common thresholds, namely hard threshold, soft threshold and half soft threshold. Whether the threshold selection is appropriate or not directly affects the effectiveness of the denoising algorithm. The threshold selection is too large, so that too many feature decomposition coefficients are set to zero, and too much image detail is destroyed;

the threshold is too small to achieve the expected denoising effect [9–10]. As a result of the traditional threshold processing method cannot achieve the requirements of denoising, the paper proposes an improved adaptive threshold denoising method, and the basic idea is as follows.

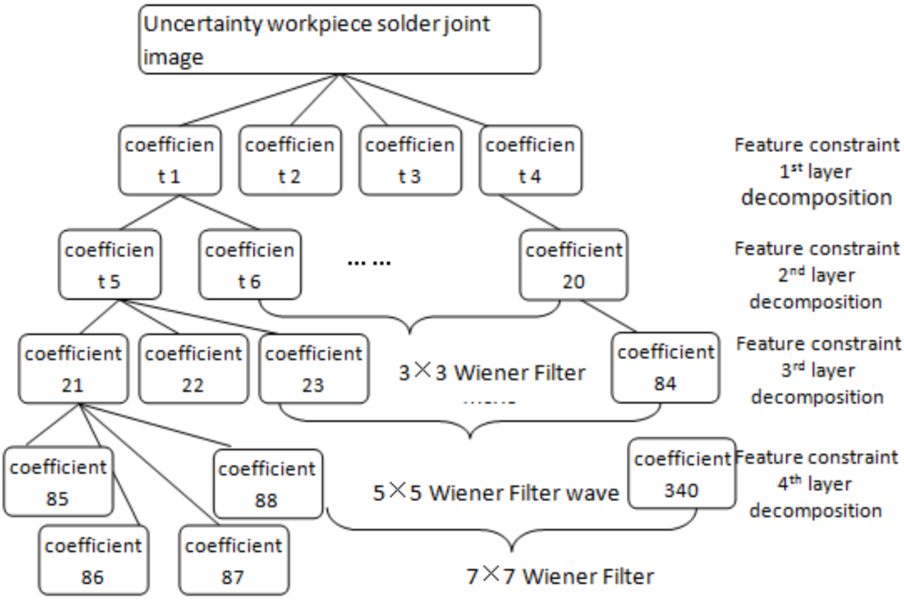

Fig. 1. Feature constraint coefficient skew filter

(1) Calculate the variance of each characteristic coefficient of the high frequency part of the feature layer decomposition

$$\sigma = \frac{\text{Median}\left(\left|w_{J,k}\left(s\right)\right|\right)}{0.6745}. \tag{1}$$

Here, J is the number of layers to be decomposed. Symbol k denotes a characteristic high frequency coefficient sequence and Median is the median function. Finally, $w_{J,k}\left(s\right)$ is the characteristic coefficient and s is the noise image.

(2) The absolute value of the variance corresponding to the characteristic coefficient calculated according to equation (1) is arranged in descending order.

(3) According to the result of the arrangement obtained in step (2), the ordered intermediate value is $\sigma_{J,M}$ and corresponding characteristic coefficient is $w_{J,s}\left(m\right)$. Symbol m is the number of characteristic coefficients.

(4) According to the result obtained in step (1), the optimal threshold value corresponding to the high frequency coefficient $w_{J,s}\left(s\right)$ in the characteristic constraint in $w_{J,d}\left(s\right)$' location $P_{J,s}$ is calculated according to the formula (2). The obtained

optimal threshold λ_s is:

$$P_{J,s} = N(s)^2 - \frac{J^J N(s)}{\sigma_{J,s}}, \tag{2}$$

$$\lambda_s = |w_{J,s}(s)|_{P_{J,s}}. \tag{3}$$

In the above formula, $N(s)$ is the width of the image after the decomposition of the Jth layer. J^J is the function after the decomposition of the Jth layer.

(5) Threshold processing of the characteristic coefficient gives

$$w_{J,s} = \begin{cases} w_{J,s}, |w_{J,s}| \geq \lambda_s, \\ 0, |w_{J,s}| \leq \lambda_s, \end{cases} \tag{4}$$

$$w_{J,s} = \begin{cases} w_{J,s} - \lambda_s, w_{J,s} \geq \lambda_s, \\ 0, |w_{J,s}| < \lambda_s, \\ w_{J,s} + \lambda_s, w_{J,s} \leq \lambda_s. \end{cases} \tag{5}$$

When $s \leq m$, the formula (4) is executed, and when $s \geq m$, the formula (5) is executed. After the characteristic high frequency coefficients are subjected to the optimal threshold processing, a new feature coefficient is obtained and the image is reconstructed The image is subjected to secondary denoising, and most of the noise in the workpiece's solder joint image has been removed, but there may be a relatively large noise that cannot be removed. Smoothing noise is used to filter the edge of the image, and finally the denoised image is obtained.

3. Based on the synergistic feature constraint and the radial singular function of the uncertainty of the workpiece solder joint image denoising algorithm flow

Based on the above principle of image noise removal based on synergistic feature constraint and radial odd function, the noise removal algorithm of workpiece free solder joint image is designed. The process is as follows.

(1) Select the highest level N of feature decomposition, the characteristics of the workpiece solder joint image decomposition; get the characteristic coefficient of each layer.

(2) Using the skewness filter method, the image feature constraint coefficient is filtered.

(3) Calculate the absolute value of the variance corresponding to the characteristic coefficient, and sort it from descending order to descending order, and obtain the intermediate value and the corresponding characteristic coefficient.

(4) According to the above-mentioned improved adaptive feature threshold calculation method, the optimal threshold is calculated.

(5) Reconstruct the feature coefficient.

(6) Smoothing the image using the median filter, the third denoising of the image,

and finally get the unpaired workpiece solder joint image. The algorithm flow is shown in Fig. 2

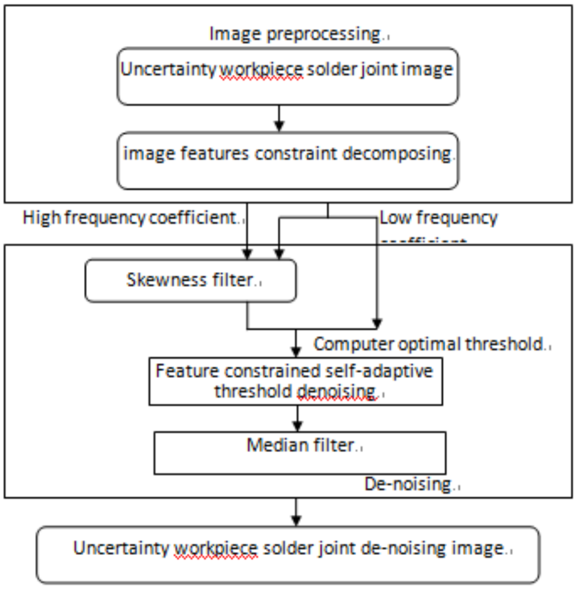

Fig. 2. Based on the synergistic feature constraints and radial singular function of the uncertainty of the workpiece solder joint image denoising algorithm flow

4. Denoising performance comparison

In order to compare the other methods and the denoising performance of the proposed method, the minimum mean square error (MSE) is used as the comparison parameter. The "Lena" images with the probability of salt and pepper noise of 0.02 and different degrees of Gaussian noise are denoised by different denoising methods to obtain the corresponding minimum mean square error, and to compare the different methods of denoising performance. The Median filter and the skew filter are 3×3, and 5×5, respectively. The synergistic feature constraints are respectively using 2, 3 and 4 layer decompositios. Only the best denoising results are listed in this paper, and the MSE results are calculated as shown in Table 1.

Table 1. Comparison of several methods of denoising performance

Method	(MSE) ε					
	σ=15	σ=2	σ=25	σ=30	σ=35	σ=40
Median	66.59	99.43	140.73	190.64	249.10	315.88
Skewness	177.08	184.30	194.37	207.69	224.83	246.11
WPM	96.64	103.30	111.33	120.62	131.17	142.75

It can be seen from Table 1 that the median filter can achieve better denoising effect when the mixed noise intensity is weak, but the performance of the characteristic combined median filter (WPM) is better than when the mixed noise is stronger Other methods.

Using SRM method, respectively, using the characteristics of two layers of decomposition, skew the window pixel size 3×3, median filter window pixel size 3×3 (method 1); Feature 2 layer decomposition, skewed window pixel 5×5, median filter window pixel 3×3 (method 2), feature 3 layer decomposition, skewed window pixel 3×3, median filter window pixel 5×5 (method 3). And for feature 3 layers decomposition, skewed window pixels 5×5, median filter window pixels 5×5 (method 4), the results are shown in Table 2

Table 2. Mining SRM method image mixed noise removal

Method	(MSE) ε					
	σ=15	σ=2	σ=25	σ=30	σ=35	σ=40
1	66.55	78.07	91.93	107.94	126.08	146.13
2	68.45	79.59	92.90	108.31	125.75	145.24
3	102.1	105.22	126.05	135.57	141.54	147.28
4	103.0	104.66	120.21	131.55	133.98	139.05

5. Uncertainty of workpiece solder joint image denoising results and comparison

Multiplicative noise is also one of the common noises in the solder joint image of uncertain parts. We choose the gray-scale image of the airfoil pin in IPC-A-610D as an example, as shown in Fig. 3, left part. After adding salt and pepper noise and multiplication, the noise is shown in Fig. 3, right part.

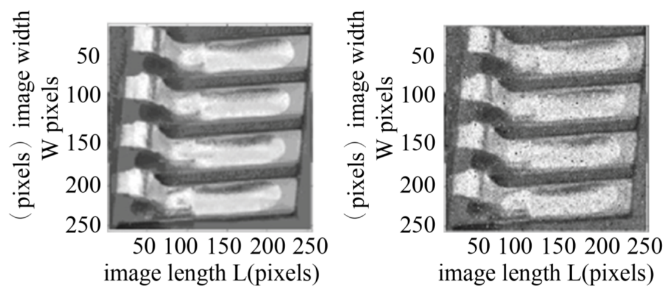

Fig. 3. Uncertainty workpiece solder joint image and noise image: left part–raw image of SMT solder joint, right part–added mixed noise

For the noise image, the median filter (window pixel size 3×3), skew filter (window pixel size 3×3), the characteristic soft threshold method for denoising, and denoising results are shown in Fig. 4.

It can be concluded from Fig. 4 that the median filter and the skew filter are not ideal for the denoising effect of the fixed part solder joint image. WPM method to remove the smaller noise has a certain effect, but for most of the noise, the removal effect is not very good, still remain in the image, using the proposed SRM method, the median filter window pixel size were 3×3, 5×5, the synergistic feature constraint is decomposed by 2, 3 layers. The results are Indicated in Fig. 5. It can be concluded from Fig. 5 and Fig. 3, right part, that the noise of the solder joint in Fig. 5 has been substantially eliminated, the denoising is achieved and the edge information is well preserved. The denoising effect is better than that shown in Fig. 4, and the effect of Fig. 5, right part, is slightly better than the effect of Fig. 5, left part.

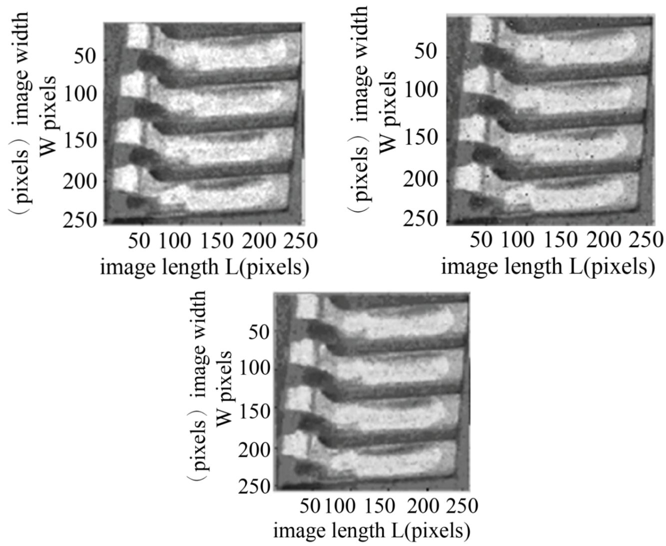

Fig. 4. Uncertainty workpiece disassembly results: left part up–median filter, right part up–skewness filter, bottom part–WPM method

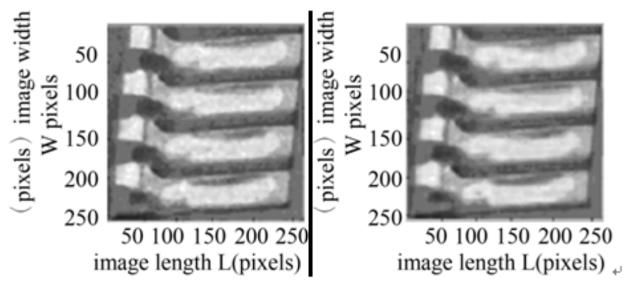

Fig. 5. Denoising results of uncertainty workpiece solder joint image: left part–AWPWM (2 layers decomposition, 3×3), right part–AWPWM (2 layers decomposition, 5×5)

6. Conclusion

(1) Using the skew filter, the characteristics of the decomposition of the high-frequency part and part of the low-frequency part of the appropriate filtering, is conducive to improving the uncertainty of workpiece solder joint image denoising effect.

(2) The improved adaptive feature threshold method is used to deal with the threshold of the characteristic coefficient, which is more reasonable than the traditional feature threshold denoising method, which can effectively remove the mixed noise in the workpiece joint image.

(3) Using the median filter on the uncertainty of the workpiece solder joint image smooth processing, while protecting the edge of the image information.

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