Study on defect spot recognition method in metal soldering based on intelligent artificial vision

Wu Zhaoyu

School of Material engineering Panzhihua University, Panzhihua Sichuan 617000, China

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Abstract. During the process of defect spot recognition among metal solder joint, if the defect spot is responsible characteristic within small region, the traditional identification method of metal solder joint defect spot is based on sparse representation, unable to express details of characteristics in small region accurately. An optimized metal solder defect spot identification model is proposed, based on the similar triangle principle to derive the relationship between the defect spot depth and weld area, using back projection map of background subtraction graph and color histogram to detect the defect spot region, and convert RBG color space to HSV color space, the color histogram in HSV space is extracted, and the brightness values of the region meets requirement need to be modified, so as to obtain the back projection image of color histogram after processing, and two value image of defect spots detection, with the algorithm based on 7Hu moment vector, on the basis of the solder joint defect spot detection two value image, through acquiring contour of defect spot to match the template in the library, so as to achieve recognition of defect spot in metal solder joint.

Introduction

With the development of computer recognition technology, intelligent artificial vision is developing toward various novel recognition model [1, 2]. Metal soldering as a metal connection mode consistent with the high performance, with characteristics of fast and firm, is regarded as an important part in metal processing [3, 4]. Therefore, identification of metal solder joint defect spot receives more and more widespread concern, viewed as the key topic by the scholars of related field [5].

During the process of defect spot recognition among metal solder joint, the process is easy to be disturbed by the fuzzy defect spot if the defect spot is responsible characteristic within small region, the traditional identification method of metal solder joint defect spot is based on sparse representation, unable to express details of characteristics in small region accurately.

An optimized metal solder defect spot identification model is proposed, based on the similar triangle principle to derive the relationship between the defect spot depth and weld area, considering the relationship, background subtraction method is adopted to detect the defect spot, on the basis of background updates, subtraction is processed to the background of current frame, using back projection map of background subtraction graph and color histogram to detect the defect spot region, and convert RBG color space to HSV color space, the color histogram in HSV space is extracted, and the brightness values of the region meets requirement need to be modified, so as to obtain the back projection image of color histogram after processing, and two value image of defect spots detection, with the algorithm based on 7Hu moment vector, on the basis of the solder joint defect spot detection two value image, through acquiring contour of defect spot to match the template in the library, so as to achieve recognition of defect spot in metal solder joint.

Recognition principle of metal solder joint defect spot based on the sparse representation

The specific process of solder joint defect spot recognition based on sparse representation is as follows: ①normalize the training samples; ②through the principal component analysis method to collect characteristics of all training samples, complete the acquisition of dimension reduction characteristics; ③classify the obtained training samples with sparse representation; ④input testing samples, repeat steps ①,②,③, through the sparse representation classification to obtain solder joint defect spot recognition results.

First, normalizing the training samples, through the principal component analysis method to collect characteristics, according to the collection of featured image to shape the dictionary matrix A.

Assuming the training samples constituted of i class defect spots is $A_i=\left[\alpha_{i1},\alpha_{i2},\cdots,\alpha_{in_i}\right]\in R^{m\times i}$, among them, $m=w\times h$, α_{ij} is used to describe a column vector, $j=1,2,\cdots,n_i$, which is used to describe the defect spot image with size $w\times h$, if n_i is large enough, for a new i class defect spot sample $y_i\in R^m$, which can be described by linear combination of i class training samples:

$$y_i \in x_{i1}\alpha_{i1}+x_{i2}\alpha_{i2}+\cdots+x_{in_i}\alpha_{in_i} \tag{1}$$

Among them, $x_{ij}\in R$; $j=1,2,\cdots,n_i$. If the training sample $A_i=[A_1,A_2,\cdots,A_c]\in R^{m\times n}$ have c categories, for the test sample y_0 of one type of classes, it can be described sparsely in all training samples as:

$$y_0 = Ax_0 \tag{2}$$

In the formula, $x_0=\left[0,\cdots,0,x_{i,1},\cdots,x_{i,n_j},0,\cdots,0\right]^T\in R^N$ is used to describe sparse vector of particular sparse; n is used to describe the number of training samples, if $m>n$, then the vector x is the only. α is obtained from minimum value $\|\alpha\|_0$, which can be described by formula (3):

$$\hat{\alpha}_0 = \arg\min\|\alpha\|_0 \; s.t.y = A\alpha \tag{3}$$

On the basis of sparse representation and the compressed sensing theory, formula (3) can be solved approximately by the following convex optimization:

$$\hat{\alpha}_1 = \arg\min\|\alpha\|_1 \; s.t.y = A\alpha \tag{4}$$

Among them, $\|\alpha\|_1$ is the α of l_1 norm, the problem can be described as tolerance error form by the standard linear equations:

$$\hat{\alpha}_1 = \arg\min\|x\|_1 \; s.t.\|y - A\alpha\|_2 \le \varepsilon \tag{5}$$

In the formula, ε is used to describe the tolerance error.

The test sample y belongs to the category of largest contact, according to the minimum residual error value to classify the samples, and identify the classification test sample belong to, i.e.:

$$identity(y) = \arg\min\|y - A_i\alpha\|_2 \tag{6}$$

Metal solder joint defect spot recognition under intelligent artificial vision

The relationship between the solder joint area and depth of the defect spot. Assuming ab represents an object, its length is L; a_1b_1 is the image of solder joint formed in the left eye of intelligent vision, the length is L_1; a_rb_r is the image of solder joint formed in the right eye of intelligent vision, the length is L_r; u is used to describe the object distance, v_1, v_r are used to describe the image distance of defect spots in the left and right eye separately; the focal length are described by f_1, f_r respectively.

Based on the basic principle of similar triangle, there is:

$$L_1 / v_1 = L / u \tag{7}$$

And, the focal length, object distance, image distance meet the following relationship:

$$1/ f_1 = 1/u + 1/v_1 \tag{8}$$

Therefore, the below formula can be obtained:

$$L_1 = L/(f_1 u) - L/u^2 \tag{9}$$

If L is sufficiently small, then the objects ab can be viewed as a point, L_1 is used to describe the area of the spot, the imaging area of defect spot in left eye of artificial vision is described with formula (10):

$$\begin{aligned} A_1 &= \sum(L/(f_1u) - L/u^2) \\ &= \sum(L/f_1)(1/u) - (\sum L)(1/u^2) \end{aligned} \tag{10}$$

Similarly, the imaging area of spot in the right eye of artificial vision can be described as:

$$A_r = \sum (L / f_r)(1/u) - (\sum L)(1/u^2) \quad (11)$$

Background subtraction method. According to the relationship between the solder joint area and the defect spot depth, $d(x,y)$ is utilized to describe the image after background subtraction, described by $f(x,y)$ is adopted to describe the current frame image, $b(x,y)$ is used to describe the background image, then the principle of the background subtraction can be described by $difference(x,y) = frame(x,y) - backround(x,y)$.

Because influenced by external factors such as light, the background in the actual scene will be changed slightly, when the error accumulates to a certain value, will cause the expected scope of defect spot can't be obtained, so the background within the scope of intelligent visual field have to be updated in real time, the specific formula described as follows:

$$B_k(x,y) = (1-\alpha_b)B_{k-1}(x,y) + \alpha_b I_k(x,y) \quad (12)$$

Among them, (x,y) is the background region, $B_k(x,y)$ represents the background image of the k frame, $\alpha_b \in [0,1]$ represents the background updating rate. If $\alpha_b = 1$, the background image of the current frame is employed to replace the corresponding regions of the prior background; if $\alpha_b = 0$, then the background is not updated; this paper uses $\alpha_b = 0.8$.

Defect spots detection combined with improved color histogram. Because the HSV color space has relatively low sensitivity to light, so HSV color space is utilized to extract the data from color histogram. Converting the RBG color space into HSV color space:

$$\begin{cases} \max = Max(R.G.B); \min = Min(R.G.B) \\ \begin{cases} H = \dfrac{G-B}{\max - \min}, if \quad R = \max \\ H = 2 + \dfrac{B-R}{\max - \min}, if \quad G = \max \\ H = 4 + \dfrac{R-G}{\max - \min}, if \quad B = \max \end{cases} \\ S = \dfrac{\max - \min}{\max} \\ V = \max \end{cases} \quad (13)$$

According to color histogram obtained after treatment, to calculate the back projection image of all frames:

$$back\_projecttion(x_i) = \sum_{u=1}^{m} \hat{q}_u \delta[b(x_i) - u] \quad (14)$$

The defect spot recognition based on invariant Hu moment. This paper adopts the 7Hu moment vector algorithm, based on two value image based of defect spots, via collecting the contour of the defect spot to match template library, so as to achieve the recognition of metal solder joint defect spots by artificial intelligence vision.

The $p+q$ order geometric moments of the defect spots image collected by intelligent artificial vision can be described as:

$$m_{p+q} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} x^p y^q f(x,y) dxdy \quad (15)$$

Central moment of $p+q$ order can be described as:

$$\mu_{pq} = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} (x-\bar{x})^p (y-\bar{y})^q f(x,y) dxdy \quad (16)$$

In the formula, $\bar{x}$, $\bar{y}$ are used to describe the gravity center of image:

$$\bar{x} = m_{10} / m_{00}$$
$$\bar{y} = m_{01} / m_{00} \quad (17)$$

η_{pq} is the normalized central moments, the following formula is used to describe:

$$\eta_{pq} = \mu_{pq} / \mu_{00}^{\rho} \quad (18)$$

In the formula, $\rho = (p+q)/2 + 1$.

Geometric moment theory of intelligent artificial vision metal solder joint defect spot image recognition, through the normalized central moments of two order and three order to create 7 translation, rotation and scale invariant moment. 7Hu invariant moment feature vectors adopted by Hu moment invariants, form a feature space (M1, M2, M3, M4, M5, M6, M7).

Analysis of simulation experiments

In order to verify the validity of the method proposed in this paper, there is the need for the related experiments analysis. The experiment used the robot SFHR, the height of it is about 60 cm, resolution for binocular camera is 640* 480, the focal length is 2.2 ~ 6.8mm. During the process of experiment, the metal object with solder joint was placed in the front of the robot, the robot started to recognize.

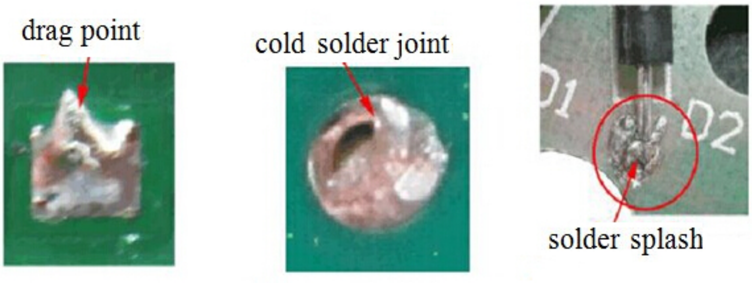

Figure 1 several metal solder joint defect spots

With the proposed method and the traditional method to recognize the above 3 spots 100 times, the obtained recognition rate results are described in Table 1.

Table 1 Comparison of recognition rate of two kinds of method

Dead spot number	recognition rate of the method in this paper,（%）	recognition rate of the traditional method（%）
1	99	80
2	97	76
3	95	77

After analyzing Table 1, we can see that the proposed method have higher recognition rate than the traditional methods, and the effectiveness of the proposed method is testified.

Based on the identification rate acquired from the above two methods, the accuracy of recognition was analyzed, the results are described in Figure 2.

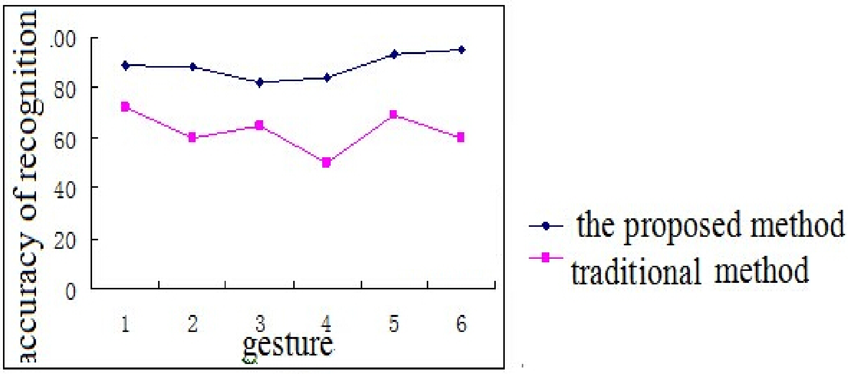

Figure 2 the accuracy of recognition obtained with the proposed method and the traditional method

It can be seen in Figure 1, the proposed method has higher than accuracy of recognition than the traditional method, the wave of accuracy of recognition is more stable, because when the difference between normal solder and defect spot is small, the traditional methods can not accurately identify them, the stability and accuracy of the method proposed in this paper is verified.

Conclusions

An optimized metal solder defect spot identification model is proposed, based on the similar triangle principle to derive the relationship between the defect spot depth and weld area, considering the relationship, background subtraction method is adopted to detect the defect spot, on the basis of background updates, subtraction is processed to the background of current frame, using back projection map of background subtraction graph and color histogram to detect the defect spot region, and convert RBG color space to HSV color space, the color histogram in HSV space is extracted, and the brightness values of the region meets requirement need to be modified, so as to obtain the back projection image of color histogram after processing, and two value image of defect spots detection, with the algorithm based on 7Hu moment vector, on the basis of the solder joint defect spot detection two value image, through acquiring contour of defect spot to match the template in the library, so as to achieve recognition of defect spot in metal solder joint.

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