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Research on Detection Technology of Micro-Components on Circuit Board Based on Digital Image Processing

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Abstract: Aiming at the stability of the circuit board image in the acquisition process, this paper realizes the accurate registration of the image to be registered and the standard image based on the SIFT feature operator and RANSAC algorithm. The device detection model and data set are established based on Faster RCNN. Finally, the number of training was continuously optimized, and when the loss function of Faster RCNN converged, the identification result of the device was obtained.

Keywords: Tiny device recognition; Image registration; SIFT feature operator; RANSAC algorithm; Faster RCN

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1. Introduction

According to the data released by the 2019 National Inspection and Testing Service Industry Statistical Report, surface defect detection of components is one of the important fields of the inspection and testing service industry [1-3]. In the process of component detection, it is necessary to consider a variety of factors comprehensively, and at the same time, select appropriate detection methods and instruments and equipment combined with the actual production environment, so as to effectively reduce the surface defect rate of components and improve the level of product quality [4-6]. At present, the detection of components is still in the stage of surface defect detection, that is, in the industry, the image of components is automatically obtained by machine vision technology, and then the image is preprocessed by digital image processing technology, gray conversion, binarization, edge processing and other processes. Finally, the surface defects of components are classified by relevant algorithms [7]. Wu *et al.* introduced a method of using MATLAB software for image pre-filtering and combined with image binarization technology to extract image features. Then, the two-pin algorithm is introduced to determine the pin defects of the chip [8]. Aiming at the influence of acquisition illumination and noise, Chen studied the image registration algorithm based on the Fourier transform,

completed the matching between the target image and the template, and used the template subtraction method to extract the defect feature area [9]. Xie *et al.* designed an improved YOLOv4 algorithm to improve the accuracy of component positioning and recognition [10]. Guo proposed an improved algorithm based on multi-scale attention and weighted cross entropy (MW-YOLOv4). Experimental results showed that the average detection accuracy of MW-YOLOv4 was 5.83% higher than that of YOLOv4 [11]. Foreign scholars have carried out many studies based on target detection methods for different types of components. Lefkaditis *et al.*'s scheme can provide a 92.3% successful recognition rate [12]. Kumar *et al.* first used LUT transformation and threshold processing for data processing, and then generated template matches for PCB board quality inspection by particle analysis [13]. Polar *et al*. focused on the classification and recycling of electronic waste, using the combined 3D and HIS data to construct a data set of capacitors, transistors, and other components to extract geometric and spectral features for the classification, recycling, and inspection of electronic components. Huang et al. selected 4 kinds of resistors and capacitors to construct 1026 data sets, established the YOLOv2 detection model, and completed the identification and localization of electronic components [14,15]. This design is to realize image registration and chip identification of tiny components of circuit boards based on the powerful computing power of MATLAB.

2. Image transformation based on RANSAC

To calculate the image transformation parameters, the following procedures are performed: First, the geometric transformation parameters of the image need to be determined by matching the feature point pairs accurately, and the solution is carried out according to a certain transformation model. The affine transformation model mainly consists of four kinds of image transformations: scaling, transect, rotation, and translation. According to the transformation model, the coordinate points in the current two-dimensional coordinate system can be transformed into the two-dimensional coordinate system of the standard circuit board image, and the parallelism of the lines in the image remains unchanged during the transformation process. Therefore, the transformation parameters between the circuit board image to be registered and the standard circuit board image are calculated based on the affine transformation model. The affine transformation from coordinate pixel point (x_1, y_1) to coordinate pixel (x_2, y_2) can be expressed as Equation 1.

$$\begin{bmatrix} \boldsymbol{x_2} \\ \boldsymbol{y_2} \\ \boldsymbol{1} \end{bmatrix} = \begin{bmatrix} \boldsymbol{a_{11}} & \boldsymbol{a_{12}} & \boldsymbol{b_1} \\ \boldsymbol{a_{21}} & \boldsymbol{a_{22}} & \boldsymbol{b_2} \\ \boldsymbol{0} & \boldsymbol{0} & \boldsymbol{1} \end{bmatrix} \begin{bmatrix} \boldsymbol{x_1} \\ \boldsymbol{y_1} \\ \boldsymbol{1} \end{bmatrix} \tag{1}$$

where the matrix is the obtained affine transformation matrix:

$$\begin{bmatrix} a_{11} & a_{12} & b_1 \\ a_{21} & a_{22} & b_2 \\ 0 & 0 & 1 \end{bmatrix}$$

Theoretically, the solution of this matrix requires at least three sets of feature points that are not on the line. However, in reality, due to the accuracy error of the feature points obtained by the SIFT algorithm, the feature points set is usually fitted as the image transformation parameters to obtain the best solution. According to the formula, the affine transformation has six parameters, so the ideal solution needs three pairs of matching feature points. The specific calculation formula is as follows:

$$\begin{cases} \boldsymbol{x_2 = a_{11}x_1 + a_{12}y_1 + b_1} \\ \boldsymbol{y_2 = a_{21}x_1 + a_{22}y_1 + b_2} \end{cases} \tag{2}$$

It is worth pointing out here that multiple similar feature points may appear during the pairing process, resulting in a mismatch. The matching error of the obtained feature points will inevitably affect the obtained transformation parameters. Therefore, RANSAC algorithm is chosen to solve the image transformation parameters in this paper.

3. Component target detection based on faster RCNN

Deep network training needs to consider the loss function to predict the training quality in the existing convolutional network and is continuously optimized during training. In Faster RCNN, two kinds of losses are generated during training, which are classification loss and regression loss. The mathematical model of the total loss function of Faster RCNN is expressed as Equation 3.

$$L(P_i, t_i) = \frac{1}{N_{CLS}} \sum_i L_{CLS}(P_i, P_i^*) + \frac{\theta}{N_{reg}} \sum_i P_i^* * L_{reg}(t_i, t_i^*) \quad (3)$$

Where, P_i is the probability of the existence of the target in the pre-selected box; is the probability that the actual target exists; t_i is the offset distance between the pre-selected box and the real target prediction; N_{CLS} is the classification parameter; N_{reg} is a regression parameter; θ is the adjustment of parameters, to make the proportion of the two losses tend to be the same; Is the classification loss; and L_{reg} is the regression loss. The transfer learning method used in this paper also gives good detection results when training with fewer boards used to collect images. This is because, when building the Faster RCNN detector, a pre-trained convolutional neural network is used as the backbone to extract the inferior features of the image, which has been trained in a large number of datasets and has an excellent ability to perform and generalize the inferior features of the image.

4. Result demonstration

In this paper, based on MATLAB-GUI designed a circuit board micro device detection system interface. This system enables people to objectively understand the detection of components and makes the detection of components visualized. The system includes the preprocessing of the collected image, such as filtering, image enhancement, and other functions, and also contains the component detection function including the identification of chip components in the circuit board. The demonstration results of circuit board component detection based on Matlab-GUI are shown in **Figure 1**.

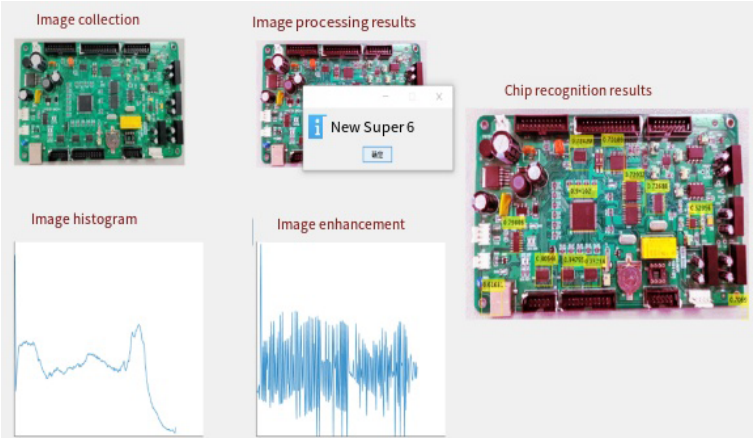

Figure 1. Demonstration of circuit board component detection based on Matlab-GUI

5. Summary

In this paper, the detection methods of tiny components of circuit boards are studied. By analyzing the advantages and disadvantages of current algorithms in the field of component detection, the target detection algorithm based on convolutional neural network is applied to the recognition and detection of circuit board components. In addition, according to the actual situation of the circuit board acquisition, the image registration operation is carried out for the collected images that may have inconsistent levels. Finally, a tiny device

detection system based on MATLAB/GUI is designed.

Disclosure statement

The authors declare no conflict of interest.

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