Capacitor Detection on PCB Using AdaBoost Classifier

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Abstract. In PCB manufacturing, automatic optical inspection (AOI) is a key technology to improve production efficiency and quality. At present, most of the AOI algorithms are aimed at PCB and SMD components. An AOI algorithm for plug-in polar capacitors is proposed in this paper. The algorithm mainly uses AdaBoost classifier based on Haar-like feature to realize the recognition of plug-in capacitors. The polarity of the capacitor is detected by comparing the image features of the target capacitor. Experimental results show that the algorithm proposed in this paper can effectively detect two kinds of defects: capacitor missing and capacitor polarity opposite. The algorithm can be applied to the AOI detection of PCB before and after wave soldering.

1. Introduction
In PCB circuits, resistors and capacitors are two main components. Resistors and small capacitors are mainly packaged by Surface Mounted Technology (SMT). Automatic optical detection technology is mainly used to detect these SMD components. There are many AOI algorithms for PCB inspection [1, 2] and Surface Mounted Devices (SMD) component detection [3], which can effectively detect defects in the manufacturing process. But these algorithms do not apply to plug-in components with Through Hole Technology (THT). THT components are big and irregular, which cannot be installed with SMT technology. These elements can only be installed manually. The traditional AOI algorithms cannot be used because the components installed manually have large offset.

There are three common AOI methods: image comparison [4], key point comparison [5] and feature comparison [6]. Image comparison method mainly detects defects by comparing pixels of standard image and test image. This method is simple to use. However, the detection at the pixel level requires higher image positioning. Due to the large position deviation of THT components, the false detection rate of image comparison teaching method is very high. The key point comparison method detects the error by locating and analyzing the key points of the element. This method has a large amount of calculation and complicated programming. In addition, due to the need for component library and key point design rule programming, it is not convenient to use. Feature comparison algorithm realizes AOI detection by feature extraction and component comparison. The feature comparison algorithm is robust to illumination variation and image quality, and has high detection accuracy. However, feature comparison algorithm has higher requirements for component recognition and location, and its performance is also affected by component position offset and spatial distortion.

An AOI algorithm based on AdaBoost classifier is proposed in this paper. It is mainly used for defect detection of THT Capacitor. AdaBoost is a machine learning algorithm. Firstly, the Haar-like texture features are extracted by AdaBoost classifier to recognize the polar capacitor. Then, the type of
capacitor error is determined by target comparison. The algorithm proposed in this paper can detect two kinds of defects: capacitor missing and capacitor polarity error.

2. Detection Algorithm

2.1. Detection Flow

The main AOI detection flow proposed in this paper is shown in figure 1, which is divided into standard image template acquisition and pre-processing, test image acquisition and pre-processing, capacitor detection and positioning, capacitor detection using AdaBoost classifier, defect record.

![Figure 1. Block diagram of detection process.](image)

The normalized image of the standard template and the test image is obtained by image acquisition and preprocessing as shown in figure 2. Step one, image acquisition by industrial camera. Step two, image equalization and noise reduction are carried out to reduce the interference of detection environment. Step three, the edge detection is used to identify the PCB frame and position the corner, so that the complete PCB image is intercepted from the background. Step four, geometric correction and normalization are carried out. This is because the camera shooting angle and PCB position change, the captured PCB image is not necessarily rectangular. Through the correction and normalization scaling, the image preprocessing obtains the standard size of the image to be used.

![Figure 2. Image Acquisition and Preprocessing.](image)

2.2. Capacitor Detection Using AdaBoost Classifier

The algorithm flow chart of capacitor detection using AdaBoost classifier is shown in figure 3. The capacitor is detected in the standard PCB image template, and the position of each capacitor is located. The corresponding position is used as the searching area of capacitor in the image to be tested. For the same board, this step only needs to be performed once. The capacitors and corresponding positions in the standard template are saved as the standard search list for capacitor detection in the test image. The search and recognition of capacitor is only carried out in the corresponding area of test image. Compared with the whole image search, it can effectively improve the recall rate and precision rate, and greatly improve the recognition speed.

In this paper, two types of capacitor defects are identified. If there is a capacitor in the standard template, but the capacitor is not recognized at the corresponding position in the test image, which is
judged as the capacitor missing error. If the capacitor is recognized at the corresponding position, the polarity of the capacitor will be compared. If the polarity is different, it is judged that the polarity of capacitor is opposite. Otherwise, there is no error.

![Algorithm Flow Chart](image)

**Figure 3.** The algorithm flow chart.

Due to the instability of the plug-in components and the inconsistency of manual installation, the position of the capacitor will be greatly offset, resulting in a large difference at the pixel level of the image. Only through the image comparison to detect, its misjudgement rate is very high. The proposed capacitor recognition algorithm uses AdaBoost classifier based on Haar feature to identify capacitance target, which can accurately recognize and locate the capacitor. The common plug-in polar capacitor has obvious texture structure, as shown in figure 4. Haar feature extraction can effectively recognize capacitor components.

![Different Capacitor Sizes](image)

\[ (a) d=15\text{mm} \quad (b) d=9.1\text{mm} \quad (c) d=5.4\text{mm} \]

**Figure 4.** Different capacitor sizes.

The capacitor classifier is trained by AdaBoost classification based on Haar texture features, and the training flow is shown in figure 5.
Figure 5. The capacitor classifier.

2.3. Polarity Judgment of Capacitor
If a capacitor is detected at the corresponding position of the capacitor in the standard template, further polarity comparison is required. The polarity comparison of capacitor adopts image comparison method, as shown in figure 6. First, the differential images of the template capacitor and the test image capacitor are calculated, as shown in figure 6c. Then binarization and morphological processing are performed, as shown in figure 6d. Finally, the connected component threshold is filtered. If there is a pair of connected components, as shown in figure 6e, the capacitor polarity is opposite. Otherwise, there is no error in the capacitor.

Figure 6. The polarity comparison.

3. Experiment Results
The industrial camera parameters used in the experiment are as follows: 5 megapixel colour CCD area array industrial camera and matching lens. There are three types of plug-in polar capacitors on the PCBs with diameters of 15 mm, 9.1 mm and 5.4 mm respectively, which is shown in figure 4.

3.1. Recognition Performance of Different Size of Capacitors
The capacitors with the following three diameters are mainly tested: d = 15mm, d = 9.1mm and d = 5.4mm. The recall rate and precision rate of capacitor recognition are shown in table 1. As the size of the capacitor becomes smaller, the recognition performance of the capacitor decreases.
Table 1. Capacitor recognition performance.

| Capacitor diameter | d= 15mm | d= 9.1mm | d= 5.4mm |
|--------------------|---------|---------|---------|
| Recall Rate        | 91.5%   | 87.6%   | 75.5%   |
| Precision Rate     | 94.7%   | 92.2%   | 84.3%   |

3.2. AOI Performance of Plug-In Polar Capacitor

The detection performance of two types of error is shown in Table 2. Among them, the precision rate of the detection for capacitor missing is about 90%. The precision rate of the detection for capacitor polarity error also about 85%. In the actual production process, the two errors are the main errors in the installation of plug-in capacitors.

Table 2. AOI performance of plug-in polar capacitor.

|         | Capacitor missing | Capacitor polarity opposite |
|---------|-------------------|-----------------------------|
| PCB1    | Recall rate       | 89.1%                       | 83.3%                       |
|         | Precision rate    | 91.8%                       | 87.2%                       |
| PCB2    | Recall rate       | 87.3%                       | 84.3%                       |
|         | Precision rate    | 92.8%                       | 87.7%                       |
| PCB3    | Recall rate       | 90.1%                       | 82.9%                       |
|         | Precision rate    | 92.3%                       | 86.4%                       |

4. Conclusion

During the installation process of PCB circuit components, the plug-in components have many appearance types and the manual installation position deviation is large. This has been the difficulty of production and testing. A capacitor AOI algorithm based on AdaBoost classifier for plug-in polar capacitors is proposed in this paper. Experimental results show that the proposed algorithm can detect two kinds of defects: capacitor missing and polarity error. For smaller capacitors, the performance of the algorithm needs to be further improved.

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