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Defect Detection In PCB By Using Hough Transform

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ABSTRACT

The aim of these inspection technique is to detect and locate any potential soldering joint defects, which will fail the functions of the final PCB products. Inspection of solder joints has been a difficult task in the electronic manufacturing industry to reduce manufacturing cost, improve quality, and ensure product reliability. This paper proposes two inspection modules for an automatic solder joint classification system. First one is ‘‘front-end’’ inspection system which includes illumination normalisation, localisation and segmentation and second one is ‘‘back-end’’ inspection which involves the classification of solder joints using the Log-Gabor filter and classifier fusion. Three different levels of solder quality with respect to the amount of solder paste have been defined which include: good solder joint, lacking solder joint and opens. The Log-Gabor filter is used to achieve high recognition rates and is resistant to uneven. This suggested system does not require any particular illumination system, and the images are obtained by an regular digital camera.

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I. INTRODUCTION

Assembly of Printed Circuit Boards (PCBs) using Surface Mount Technology (SMT) has been widely used in the electronic industry recently. As a result, the electronic components rely on the solder joint to provide the electrical connection to the PCBs; therefore, the quality of the solder joint can be critical to the quality of the electronic components. Automatic Optical Inspection (AOI) of solder joints has been a critical issue for quality control in PCB assembly as AOI has the enormous potential of completely automating human visual inspection procedures [1].

Surface Mount Technology (SMT) has become the dominant assembly technique in the electronics industry. A huge number of electronic components are packed onto small printed circuit boards (PCBs). However, risk of manufacturing problems rises when the number of mounted electronics increases. According to the certain literature and technical reports, almost 70% of surface mount PCB manufacturing failures are related to solder paste printing process. The quality of deposited solder pastes therefore becomes more important to ensure the long term reliability of PCBs. In addition, calculations have shown that pre-reflow print failure can cost 10 × less than the post-reflow, 70 × less than in-circuit test, 700 × less than a field failure.

Therefore, solder paste inspection is an indispensable

process for minimizing soldering defects and to save manufacturing costs [4].

Automatic optical inspection (AOI) is a crucial step in the manufacturing process of Printed Circuit Boards (PCBs). The quickly increasing resolution, quality and speed of industrial cameras have recently opened several new prospects in image based verification. At finer scales a significant amount of information is revealed, which calls for shifting from simple segmentation or morphology-based investigations towards a hierarchical modeling approach of the PCB structure, focusing jointly on circuit regions, individual Circuit Elements (CEs), CE interactions and relevant CE parts [2].

The aim of these inspection procedures is to detect and locate any potential solder joint defects, which will impede or break down the functions of the final PCB products. Common solder joint defects which are of concern include: good solder no solder, opens and shorts. In this study, a computer vision system is suggested for the automatic detection, localisation, segmentation and classification of solder joints on PCBs under different illumination conditions. This paper introduces a new technique for solder joint defect classification using the Log-Gabor filter and classifier fusion which has been demonstrated to achieve a high recognition rate and is resistant to uneven. Further testing demonstrates the advantage of the Log-Gabor filter over both Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) [1].

II. RESEARCH METHODOLOGY FOR AUTOMATED INSPECTION SYSTEM

This section will outline the inspection procedure involved in the automatic vision-based inspection system for solder joint classification. There are four main tasks in solder joint classification: image capture, segmentation, feature extraction and classification. Several inspection algorithms have been applied for each task. Block dig 2.1 represents the detailed methodology for the solder joint defect classification system proposed by this research. The first step is acquisition of the image. The image acquired by the camera contains the components and solder joints to be classified and other irrelevant zones within the image. Thus, the important Region of Interest (ROI) must be extracted from the acquired image. To extract the ROI, the Hough Transform is utilized for automatic alignment of the PCB. Afterwards an illumination normalisation technique is applied to an image, which effectively eliminates the effects of uneven lighting conditions. Following this, the image is transformed from an RGB to a YIQ colour model for the effective detection of solder joints from the background. This is then followed by thresholding, region filling and segmentation of solder joints [1].

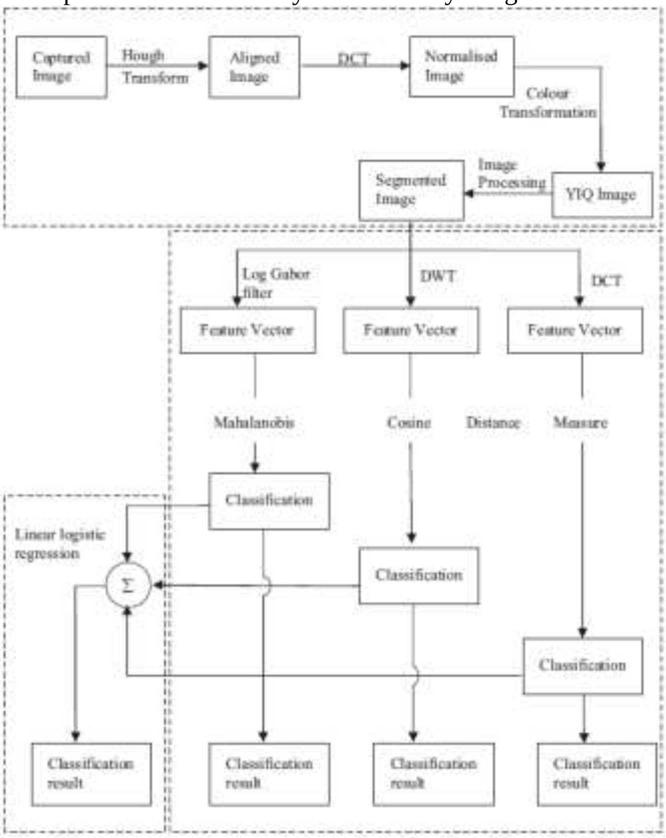
The next step of the diagnosis process is the feature extraction. In this step, features are extracted by three different methods: Log-Gabor filter, Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). Finally, these features are measured by Mahalanobis Cosine distance and three types of solder joints are classified. These include: good solder joint, less solder joint and bridge solder joint. The method for combining information is examined to improve the accuracy and robustness for the classification of solder joints.

The main idea behind the proposed method is to segment the area of the solder joint, which we refer to as the Region of Interest (ROI), and extract some features that are crucial for detecting the suspect joints. One property of the imaged solder joints in processor sockets is that they are aligned in parallel horizontal lines and parallel vertical lines when the images are captured at a 90 angle relative to the board (top view). However, as stated before, top-view images do not provide a good detection capability for non-wets as these become hard to distinguish from the non-defective joints. Taking images with oblique angles helps in distinguishing non-wet joints from the good ones. However, in this latter case, the joints are no longer aligned on vertical and horizontal lines. The solder joints are still aligned in straight lines; however, these lines are not necessarily parallel. Also, the imaged joints exhibit variations in shape and size within the same image and across images due to perspective effects when imaging at oblique angles [2].

2.1. HOUGH TRANSFORM

The Hough transform is a technique which can be used to isolate features of a particular shape within an image. Because it requires that the desired features be specified in some parametric form, the classical Hough transform is most commonly used for the detection of regular curves such as lines, circles, ellipses, etc. A generalized Hough transform can be employed in applications where a simple analytic description of a feature(s) is not possible.

The main advantage of the Hough transform technique is that it is tolerant of gaps in feature boundary descriptions and is relatively unaffected by image noise.



Block dig 2.1 Inspection procedure.

Fig.1. Acquired image.

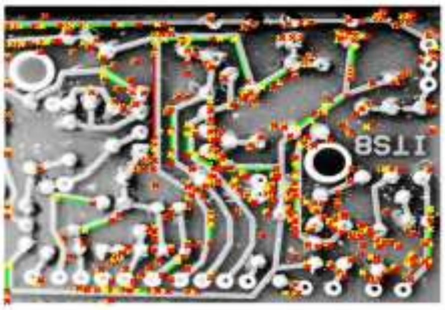


Fig. 2. Result of Hough Transform

The Hough transform is a powerful method for detecting edges. It transforms between the Cartesian space and a parameter space in which a straight line can be defined. The advantage of the Hough transform is that the pixels lying on one line need not all be contiguous.

This method is very useful when trying to detect lines with short breaks in them due to noise, or when objects are partially occluded. For this reason, the Hough transform technique is used to locate the PCB so that the PCB does not need to be placed onto a precision X–Y table. In this way the PCB can be located on an automatic conveyor line, without interrupting the line production [1].

$$\rho=x\cos(\theta)+y\sin(\theta). \quad (1)$$

In this approach, images are normalised using the Discrete Cosine Transform (DCT) technique to normalise the images to appear stable under different lighting conditions [1].

2.2. COLOR TRANSFORMATION

It is not easy to separate the solder joints and other background information from a PCB image as there are many lines and markings that have similar values as the solder joint [6]. In this case, the PCB image is transformed from an RGB colour model to YIQ colour model.

2.2.1. THRESHOLDING

After performing the colour transformation of an image, a solder joint needs to be extracted from its background by a threshold selection. If the object has a often difficult to select an suitable threshold. In this research, a successive iterative process is described to achieve an optimum threshold. The histogram of an image is initially segmented into two parts using a starting threshold value such as half the maximum dynamic range. Then, the sample data are computed into two classes, which are the sample mean of the grey values associated with the foreground pixels and the sample mean of the grey values associated with the backdrop pixels. Then a new threshold value is determined as the average of the above two sample means. The resultant threshold and its upper and lower thresholds are applied to the PCB image. Then the new threshold value is calculated according to the number of components detected. This process is repeated until the number of components does not change any more [1].

The easiest thresholding methods replace each pixel in an image with a black pixel if the image intensity is less than some fixed constant T or a white pixel if the image intensity is greater than that constant [7].

2.2.2. REGION FILLING

Although the solder joints have been identified, closed or opened holes might arise on solder joints after segmentation because of the surface property and shape of solder joints. These holes can be confusing when determining the solder joint location. Accordingly these holes need to be restored. Firstly, erosion and dilation via morphology is applied to enclose an opened hole. If dilation of Morphology is used to enclose hole, it might change the original shape of the solder joints. In that case, Region Filling is applied to mend these closed holes. Region Filling is depends on set expansion, complementation, and intersections [1].

2.2.3. SEGMENTATION PROCESS

There are two stages in the segmentation process. In the first stage of segmentation, components are extracted from the acquired image and the next step is to extract an image of the solder joint from every component. In executing the first step of segmentation, the pixels which represent components and background are grouped into important regions. The white pixels correspond to components and black pixels correspond to backdrop. Once an item pixel is found, the entire connected object region is compute. Finally, the centroid of the region is intended as a simple measure of object location. For the next step of segmentation, every solder joint can be friendless by projection of the image horizontally and vertically. Each lead pad pair can be friendless by vertical projection and the solder region can be identified be by horizontal projection [1].

Image segmentation is the process of partitioning a digital image into several segments. The aim of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and simpler to analyze. Image segmentation is typically used to show objects and borders in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain characteristics.

III.CLASSIFICATION OF SOLDER JOINTS

3.1. LOG-GABOR FILTER

Gabor filters are a traditional choice for obtaining localised frequency information. They give the best concurrent localization of spatial and frequency related information [5]. An important property of the Gabor filter is that it has optimal localisation properties in both the spatial and frequency domain. A two-dimensional Gabor filter consists of a sinusoidal plane of the particular frequency and orientation modulated by a two dimensional Gaussian envelope. The two main components of the Gabor filter are the complex sinusoidal carrier s(x) and the Gaussian envelope $\omega_r(x)$. These components are expressed as [1],

$$s(x)=\exp\{2\pi jk\hat{}Tx\} \quad (6)$$

There are two important characteristics in the Log-Gabor filter. Firstly the Log-Gabor filter function always has zero DC components, which contribute to improve the contrast ridges and edges of images. Secondly, the Log-Gabor function has an extended tail at the high frequency end, which allows it to encode images more efficiently than the ordinary Gabor function. The Log-Gabor filter has a Gaussian transfer function when viewed on algorithmic frequency scale instead of a linear scale [1].

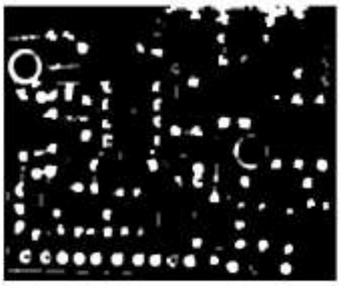


Fig.4. Result Log Gabor filter

3.2. DISCRITE WAVELATE TRANSFORM

Wavelet decomposition is the projection onto an orthonormal set of basis vectors which are generated by dilation translation of in a ‘‘mother wavelet.’’ The simple mother wavelet is the Haar wavelet. The ‘‘mother wavelet’’ has low-pass and high-pass responses. At each application of the filters, the signal is break into a low and high frequency component, which are then down sampled by a factor of two to give a consistent memory requirement regardless of decomposition level. This also allows the same filters to be used at each level as they have effectively been up scaled by a factor of two.

There are many popular wavelet families being used in different applications such as Daubechies and Coifed wavelets. The equal error rate (EER) of the Daubechies wavelet transform (level 2) is 5% and the EER of the Daubechies wavelet (level 4) is slightly more than 5%. However, they have the disadvantage of being more computationally expensive than the Haar wavelets. The it has transform has a number of advantages:

- It is conceptually simple.
- It is memory efficient, since it can be intended in place without a temporary array.

3.3. DISCRETE COSINE TRANSFORM

A discrete cosine transform (DCT) expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies.

The Discrete Cosine Transform (DCT) has been widely used in feature extraction and image compression because it has the effect of concentrating the energy in a signal in a relatively small number of coefficients. A detected and normalized image is divided in to blocks of N*N pixels size.

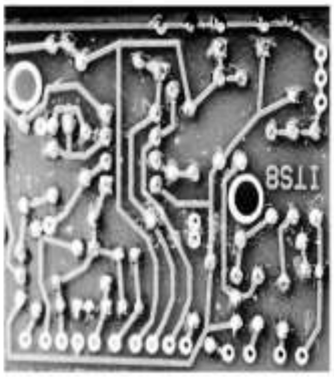


Fig. 3. Reconstructed image by applying the DCT.

IV. CLASSIFIER FUSION

This section, a method for combining the information from these classification systems is examined. Fused classification aims to improve the accuracy and robustness of a classification system by combining multiples sources of information. These information sources need to be complementary as redundant information will not improve conformation. Classifier fusions merge the information from multiple verification systems that are achieved from three different classifiers. The advantage of the linear classifier fusion technique is that complex data and feature normalisation methods do not need to be employed.

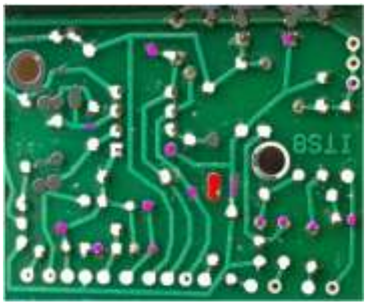


Fig.5. final result

Table 1

Summary result for recognition rate of solder joints across three categories by using Log-Gabor filter.

Solder joint types	**Recognition rate**
Good solder Joint	68
lacking solder joint	9
Opnes	14

V.CONCLUSION

This paper has provided some optical inspection techniques and has proposed two inspection modules for an automatic solder joint classification system. The ‘‘front-end’’ inspection system proposed a illumination normalisation approach for solder joint segmentation. Illumination variations under dissimilar lighting conditions can be significantly reduced by discarding low-frequency DCT coefficients. This approach has advantages in: (1) no modeling steps are required and (2) this approach is fast and it can be easily implemented in a real-time solder joint segmentation system.

The ‘‘back-end’’ inspection involves the classification of solder joints by using the Log-Gabor filter and classifier fusion. Three dissimilar levels of solder quality regarding the amount of solder paste have been described. The Log-Gabor filter was denoted to carry out high recognition rates and is resistant to uneven. Further testing denotes the advantage of the Log-Gabor filter over both the Discrete Wavelet Transform and the Discrete Cosine Transform. Classifier score fusion was analyzed for improving the recognition rate. The Classifier score fusion was approached as a linear score fusion since this method treats each source independently so that information from the sources can be maximized

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