Various Techniques for PCB Defect Detection

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Abstract: Printed Circuit Boards are by far the most common method of assembling modern electronic circuits.During the manufacturing of PCB many defects are introduced which are harmful to precision circuit performance. A variety of ways have been established to detect the defects found on PCB, but it is also necessary to classify these defects so that the source of these defects can be identified.Automated visual printed circuit board inspection is an approach used to counter difficulties occurred in manual inspection. This paper reviews various techniques for PCB defect detection and classification using image processing.

Keywords:Image Processing, PCB, Wavelet Transform, Morphological Operators, Image Subtraction.

1) Introduction

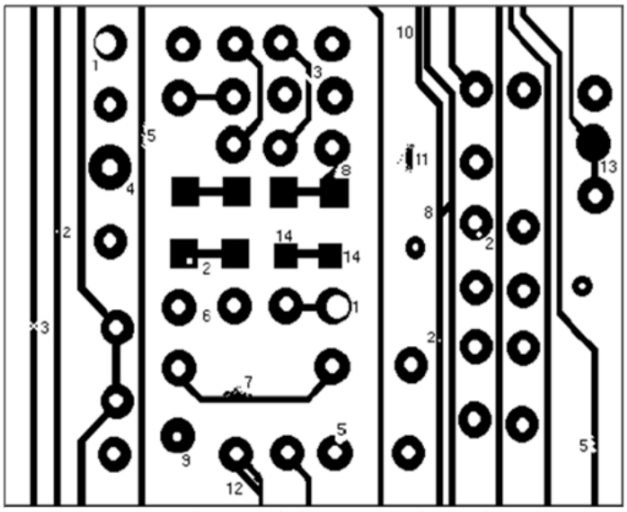
A printed circuit board (PCB) mechanically supports and electrically connects electronic components using conductive tracks, pads and other features etched from copper sheets laminated onto non-conductive substrate. One of the key components of electronic industries is the production of the PCB. In order to reduce cost spending in manufacturing caused by the defected bare PCB, the bare PCB must be inspected. Mogati et al.[1] proposed three categories of PCB inspection algorithms: referential approaches, non-referential approaches, and hybrid approaches.

- Referential approaches consist of imagecomparison and model-based technique.
- Non-referential approaches or design-ruleverification methods are based on theverification of the general design rules thatis essentially the verification of the widthsof conductors and insulators.
- Hybrid approaches involve a combinationboth of the referential and the non-referential approaches.

The use of manual labour to visually inspect each PCB is no longer viable since it is prone to human errors, time consuming, requires large overhead costs and results in high wastage. Thus an automation inspection system is highly desirable.

1.1) PCB Defects

PCB defects can be categorized into two groups: functional defects and cosmetic defects [1]. Functional defects can seriously affect the performance of the PCB or cause it to fail. Cosmetic defects affect the appearance of the PCB, but can also jeopardize its performance in long run due to abnormal heat dissipation and distribution of current. There are 14 known types of defects for single layer.



1. Breakout2.Pin hole3.Open circuit4. Under etch

5.Mouse bite6.Missing conductor7. Spur8. Short9.Wrong size hole

10. Conductor too close11.Spurious cooper12.Excessive short13.Missing hole14.Overetch

Fig.1 Various defect on a Bare PCB

2) defect detection techniques

Numerous PCB inspection algorithms have been proposed in the literature of Moganti [1]. He divided the PCB inspection algorithms into three main categories: reference comparison, non-referential, and hybrid approach.

A. Referential approach

The referential approach compares the test PCB image against the reference PCB image. These methods execute feature–to- feature comparison whereby the reference data from the surface image of a good sample is stored in the image database. These methods detect errors like missing tracks, missing terminations, opens, shorts, etc. it includes two major techniques: image comparison and model - based technique.

1) Image comparison: Comparison technique consists of comparing both images using XOR logic operator. It is based on assumption that, any difference between the reference and test image is considered as a defect. The operation is simple but the main constraint found in this method is on achieving a precise alignment of the reference PCB and testPCB. Wen-yen[3] did direct subtraction of reference and test image to get positive, negative and equal pixelsand compared these images to get the defects. Hara[15] extracted the features of boundary lines and small line width patterns by extraction operators which were used compared to identify the defects.

2) Model-Based Techniques: These methods begin with conversion of images into a predefined model before inspection execution takes part based on the model. Numerous techniques were proposed under this category they are tree representation connectivity based technique which is limited to identify only missing hole or excessive short and open circuit only, N-tuple technique and run length encoding based technique. Run length encoding is the best among all other model based methods. Under this method a PCB image is compressed in RLE data and image difference operation is done this data.

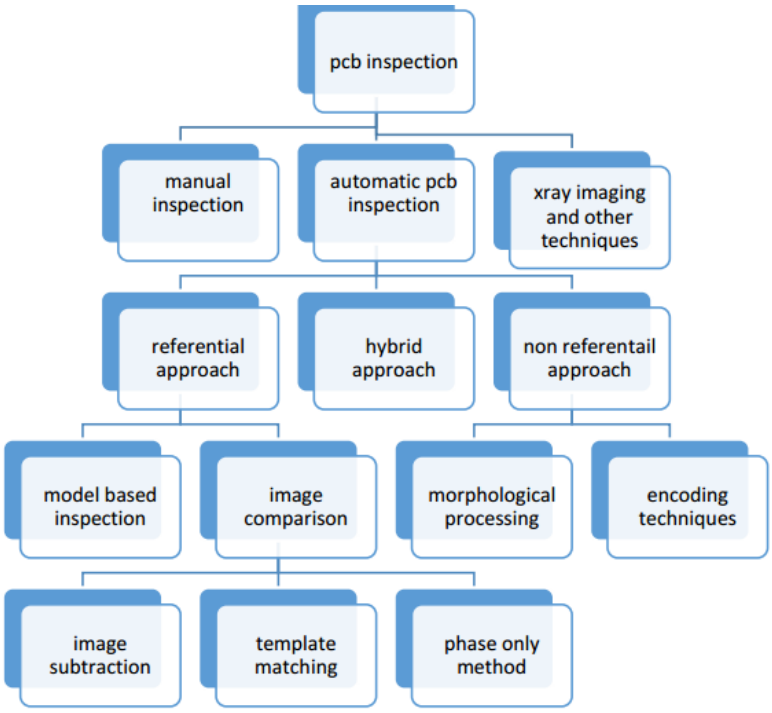


Fig. 2 Classification of Detection Techniques

2.1) Non-Referential approach

Non-referential approaches or design rule verification methods are based on the verification of the general design rules that is essentially the verification of the widths of conductors and insulators.These methods either work on the assumption that features are simple geometric shapes and the defects are unexpected irregular features or on directly verifying the design rules. The non-referential approaches use the knowledge of properties common to a circuit family but not knowledge of the specific circuit under test. Non-Referential methods do not need any reference pattern to work with; they work on the idea that a pattern is defective if itdoes not conform to the design specification standards. Morphological processing and encoding techniques come under this approach.

1). Morphological approach: It is one of the widely used techniques in PCB inspection. The inspection involves the expansion-contraction process, which does not require any predefined model of perfect patterns. Morphological operators are applied on the bare PCB board. Few of morphological operators are Erosion, dilation,opening, closing, and boundary extraction. The basic process of defect detection using morphological operators can be implemented only to detect the defects in tracks.

2).Encodingtechniques:It includes boundary analysis techniques. Boundary analysis techniques studied are based ontherepresentationoftheboundariesinatractableform,followedbyarule verification procedure.

C. Hybrid approach

It is a combination of the reference –based and non-reference based approaches. The hybrid flaw-detection techniques increase the efficiency of the system by making use of both referential and design-rule techniques exploiting the strengths and overcomingthe weaknesses of each of the methods. Thesemethods have the added advantage that they cover alarge variety of defects compared to either referentialor non-reference methods alone. For example, mostof the design-rule verification methods are limited toverifying minimum conductor trace and land widths,spacing violations, defective annular ring widthsangular errors, spurious copper. Printed circuit boarderrors which do not violate the design rules aredetected by reference comparison methods. Thesemethods can detect missing features or extraneousfeatures like isolated blobs, etc. The design-ruleprocess detects all defects within small and mediumsized features; the comparison methods are equallysensitive right up to the largest features. Hybridsystems make use of both the design-rule methodsand comparison methods as they complement eachother and therefore achieve 100% error sensitivity,irrespective of feature sizes on the printed circuitboards.

3) Existing algorithms

Heriansyah, et al. [1], [2] proposed a technique thatclassify PCB defect using neural network. This algorithmsegments the images in to basic primitive patterns.Enclosing the primitive pattern, pattern assignment,pattern normalization and classification where developedusing binary morphological image processing andlearning vector quantization (LVQ) neural network. ThePCB defect could be formed into three group, the defectson the foreground only, the defects on the backgroundonly, and the defects on both foreground and background

Khalid, et al. [4] Proposed algorithm that can beimplemented on the bare PCB to identify and to groupPCB defects. However, the major limitation of thisalgorithm is that the proposed algorithm is developed towork with binary images only, whereas the output fromthe cameras is in gray scale format.S. H InderaPutera et al. [3], [10] did improvement inKhalid's work by classifying seven groups. This is doneby combining image processing algorithm and thesegmentation algorithm. Each image is segmented intofour patterns and then produced five new images for eachpair of segmented reference and test images processedand thus 20 new images produced. Out of which, sevenimages were beneficial for defect classification. Theresult of this particular experiment was each groupconsists of 1 defect and maximum 4 defects and thusimproved the work done by Khalid by an increasingnumber of groups from 5 to 7.

SonalKaushik et al.[13] applied Machine Vision PCB Inspection System at the first step of manufacturing, i.e., the making ofbare PCB. First they compared a PCB standard image with aPCB image, using a simple subtraction algorithm that canhighlight the main problem-regions. The authors have alsoseen the effect of noise in a PCB image that at what level thismethod is suitable to detect the faulty image. Focus of thispaper is to detect defects on printed circuit boards & to see theeffect of noise. Typical defects that can be detected are overetchings (opens), under-etchings (shorts), holes etc.

The authors Malge and Nadaf [10] proposed a PCB defectdetection and classification system using a morphologicalimage segmentation algorithm and simple the imageprocessing theories. However, besides the need to detect thedefects, it is also essential to classify and locate these defectsso that the source and location of these defects can beidentified. Based on initial studies, some PCB defects can onlyexist in certain groups. Thus, it is obvious that the imageprocessing algorithm could be improved by applying asegmentation exercise. This proposal uses template and testimages of single layer, bare, grayscale computer generatedPCBs

K.kaur and B.kaur[14] proposed an algorithm to group all 14 defects found on PCBinto 5 Groups .the proposed algorithm involves MATLAB image processing operations ,such as image subtraction,image addition, logical XOR, Flood fill, Opening ,erosion.Most of the defects like wrong size hole,missing hole, missing conductor, pin hole are successfully detected without any misclassification

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