Detection of Faulty Region on Printed Circuit Board With IR Thermography

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Abstract— This paper presents detection of faulty region of PCB by thermal image processing. Thermal imaging is used for analysis of thermal reliability of PCB. With variation in temperature fault can be detected. To detect faulty region, thermal image of a faultless PCB and faulty PCB is taken by the thermal camera and comparison is done for defect detection. Here feature extraction is done with Principal Component Thermography (PCT). The Principal component analysis (PCA) applied on thermographic image data is called as Principal Component Thermography (PCT). The PCT used for processing IR sequences is mainly based on thermal contrast evaluation in time. The SVD computation technique is used in place of actual PCT to reduce the amount of computation that is needed. Then Euclidian distance is used to detect faulty region by comparing features. So faulty region is get detected.

Index Terms— Thermal Images, PCT, SVD, PCA, PCB Defect, ATE

1 INTRODUCTION

Electronic equipment develops continuously toward light, thin, small miniaturization trend. As integrated electronic components and its high heat density is increasing so, small size, compact layout, high temperature greatly reducing the service life of components. It resulting to job insecurity or failure of components, and then reducing system reliability. Therefore, the thermal design becomes increasingly important.

The complexity of PCB manufacturing has increased drastically, progressing from straightforward double-sided boards with 100% through-hole technology to highly-complex multi-layer PCB's with mixtures of through-hole, surface mount and chip-on-board configurations. Board layouts have consequently increased in density with tighter tolerances and decreased distances between electrical contacts. With this increase in complexity the possibility of manufacturing defects has also consequently increased.

The several nondestructive diagnostic techniques have been developed to facilitate the Automatic test equipment (ATE). These include optical imaging, X-ray imaging, magnetic field mapping, and thermal imaging approaches. Among all the methods, the thermal image of PCB can significantly reveal the faults such as the broken internal connection; short-circuit loop, open-circuit node, power supply failure, signal interaction, and component malfunction. In addition, the thermal imaging diagnostic system has the advantages of no contact problem, rapid image acquisition, easy operation, and simple testing reconfiguration.

Some authors have done work on temperature analysis of PCB with different techniques on thermal imaging. Thermal analysis on PCB is done with Galerkin approach, here FEM model is used to study and analyze temperature rise on PCB for different width of copper and different amount of current [4]. Another analysis on thermal reliability of component on PCB is done with ANSYS software to improve reliability of system [3]. Then qualitative based measurement of thermal anomalies is done by detecting feature point and region of interest with MSER and matched with Euclidian distance [7]. Fault diagnosis for components location on PCB is done with feature point algorithm [1]. Analysis for PCB for fault diagnosis is done with vector quantization and feeding that data to neural network [2]. Again same study is done with support vector classifier and neural network [10].

The generally used thermal features include peak temperature, mean temperature, maximal temperature gradient, and temperature difference measures. To facilitate the processing of the infrared image sequences generated using different heating techniques we use the statistical analysis tool Principal Component Analysis. Here PCA is applied

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for data compression carried and better pattern matching is carried out. The Principal component analysis (PCA) applied on thermographic image data is called as Principal Component Thermography (PCT). The SVD computation technique is used in place of actual PCT to reduce the amount of computation that is needed. The feature extraction of the thermal image is acquired from the designed system setup and fed to the Euclidian distance for fault diagnosis and identification.

2 THERMAL IMAGE ANALYSIS

The human eye can only see a very small part of the electromagnetic spectrum(visible light). At one end of the spectrum we cannot see ultraviolet light, while at the other end our eyes cannot see infrared. Infrared radiation lies between the visible and microwave portions of the electromagnetic spectrum, shown in Figure 1. The primary source of infrared radiation is heat or thermal radiation.

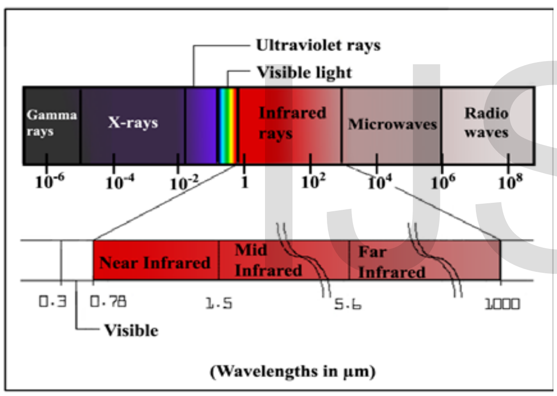

Figure 1. A Spectrum of Electromagnetic Radiation

For the sake of completeness, the basics of the temperature and thermal radiation are briefly summarized in the following. Any object with the temperature above 0 K will radiate thermal energy over all wavelengths which may be described as [2].

$$W(T) = \sigma T^4 \qquad (1)$$

Where σ denotes the Stefan–Boltzmann constant ($5{,}670 \times 10^{-8}\ W/m^2K^4$), and is absolute temperature K. In practice, no objects would radiate the thermal energy as the ideal blackbody does. Thus, (1) should be modified to

$$W(T) = \in \sigma \qquad (2)$$

Where $\in$ is the emissivity of the object $(0 < \in < 1)$. In this experiment, the emissivity for the same type of printed circuit board is assumed to be constant and may be neglected in the fault diagnosis. In other words, only the relative temperature changes between BUT and the gold thermal image are used for PCB function diagnosis.

3 METHODOLOGY

In the thermal image processing the well-known "gold thermal image" has been used in all methods. The thermal features defined for the gold thermal image includes the rate of temperature change, peak temperature, averaged temperature, and hot spots. The more the features used, the more the memory size will be required. The thermal image for the printed circuit board under test is then compared with these gold thermal images in sequence. Therefore, how to concurrently process the gold thermal image become the interesting issues in PCB analysis. Thermal image of PCB with high resolution camera is shown in Figure 2.

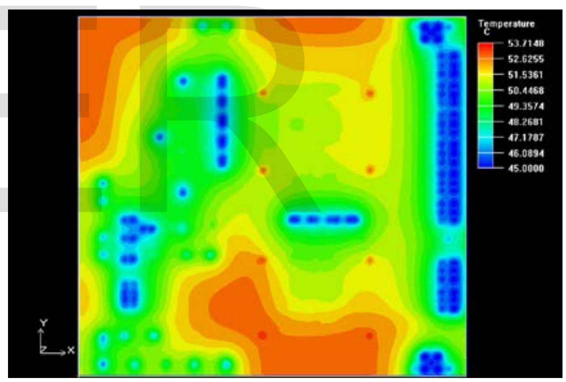

Figure 2. Thermal Image of PCB

A. Principal Component Thermography

Principal component thermography technique use to process the IR image sequences obtained from testing composite structures to enhance the contrast of acquired images. The Principal component analysis (PCA) applied on thermographic image data is called as Principal Component Thermography (PCT). The proposed PCT is a statistical analysis tool applied to multivariate data. The method helps to reduce the unwanted noise levels present in the captured image sequences and increase the contrast of the processed images compared to unprocessed data. We use a set of orthogonal statistical modes to enhance the contrast of the captured thermal images. The SVD base PCA is used

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to actual PCT due to the volume of image data captured in a single thermographic experiment. In the SVD based PCT the IR sequences are subject to preprocessing to normalize the data to reduce the effects caused by reflection and disturbances from surroundings. Once the normalization is completed we apply the PCT on the data and the first empirical orthogonal function is plotted to obtain the enhanced image. In PCT the first two or three empirical orthogonal functions contain nearly 90 percent of the variability of the image data and the remaining variability is present in the corresponding functions which can be neglected due to huge computation requirements. The computation procedure of SVD based PCT is described in the following section.

B. *Singular Value Decomposition*

The thermal image sequence containing the information about the sample is processed using SVD based PCT. The 3D image matrix is converted to 2D matrix using the similar method as described in actual PCA to build the raster like matrix A. The raster matrix A consists of Nt as matrix rows, NxNy as matrix columns as shown in figure 3.

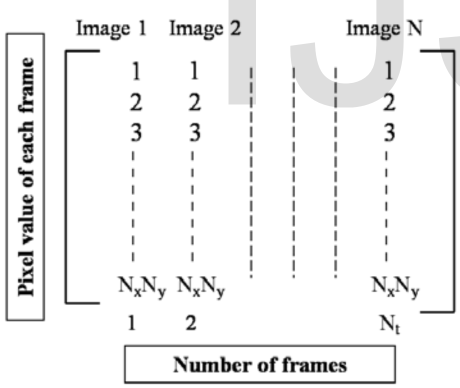
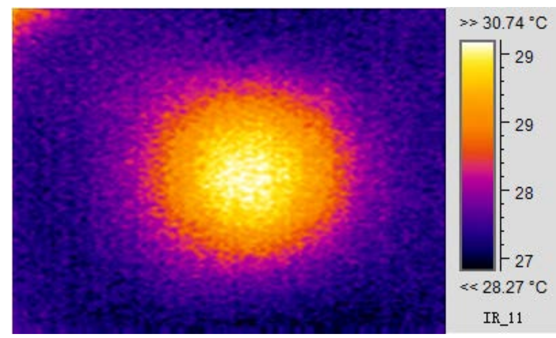


Figure.3 2D raster matrix with image sequence

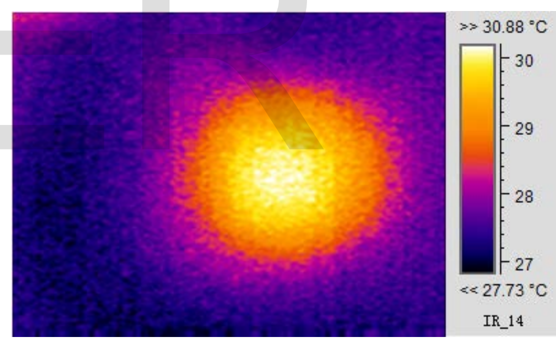
Once we have the raster like matrix A, the mean from each data point is subtracted to create zero-centered data. Each column of the raster matrix has all pixel values of an image frame. The mean image is the mean of the values of each column. Thus the standardization is done. Once the zero centered data is calculated, the SVD transformation is applied to find the Eigenvalues and eigenvectors using equation 3.

$$A = USV^T \qquad (3)$$

Input thermal images given to system are as shown in Figure 4. Firstly PCT of Faultless template images has done and stored. Later on PCT of Test images are obtained and these results are compared with Euclidian distance. Euclidian distance calculates the distance between coordinates, for minimum distance shows match n for maximum distance detect fault.



(a)



(b)

Figure.4 (a) Faultless PCB Thermal Image, (b)Test PCB Thermal Image

C. *Euclidian Distance*

All the *M* by *N* images are easily discussed in an *MN* dimensional Euclidean space, called image space. It is natural to adopt the base $e_1, e_2, \ldots, e_{MN}$ to form a coordinate system of the image space, where e_{KN+l} corresponds to an ideal point source with unit intensity at location (k,l) . Thus an image $x = (x_1, x_2, \ldots, x_{MN})$, where x_{kN+l} is the gray level at the (k,l) th pixel, is represented as a point in the image space, and x_{kN+l} is the coordinate with respect to e_{KN+l} . The origin of the image space is an image whose gray levels are zero everywhere.

Although the algebra of the image space can be easily formulated as above, the Euclidean distance of images (i.e. the distance between their corresponding points in the image space) could not be determined until the metric coefficients of the basis are given. The metric coefficients g_{ij} i,j=1,2,….,MN , are defined as

$$g_{ii} = < e_i \, , \, e_i >$$

$$g_{ii} = \sqrt{< e_i \, , \, e_i >} \, \sqrt{< e_i \, , \, e_j >} . cos\theta_{ii} \quad (4)$$

where <,> is the scalar product, and θij is the angle between e_i and e_j . Note that, if $< e_i \, , \, e_i > = < e_j \, , \, e_j > = \cdots$,i.e. all the base vectors have the same length, then g_{ij} depends completely on the angle θ ij . Given the metric coefficients, the Euclidean distance of two images x, y is written by

$$d_E^2(x,y) = \sum_{i,j=1}^{MN} g_{ij} (x^i - y^i)(x^j - y^j)$$

$$= (x-y)^T G (x-y) \qquad (5)$$

where the symmetric matrix $G = (g_{ij})_{MN \times MN}$ will be referred to as metric matrix.

4 EXPERIMENTATION AND RESULTS

Proposed algorithm has been implemented in MATLAB 7.10 on a 4GB RAM of 2.53GHz Intel Core i5 processor PC. Thermal Images of PCB has taken by Thermal imager of Testo, which is having temperature range of 20^0 C to 280^0 C with accuracy of +/-2^0 C. These thermal images are RGB JPEG files. We have evaluated the performance of our proposed algorithm by using the PCT. PCT of all training image was obtained and stored as feature vector. Each of the test thermal images used for fault detection process was matched with training images to produce correct and incorrect Euclidian distance, from that got faulty image and detected faulty region.

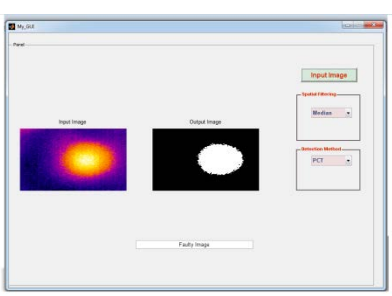


Figure.5 Faulty region is detected

5 CONCLUSION

From the sample experiment, the bare PCB is analyzed by taking thermal images and the defected area of PCB gets detected. For defect detection first PCT applied on faultless thermal images and S, U, V matrices are obtained and stored. Then the PCT is applied on test thermal images of PCB then these matrices get compared with Euclidean distance and fault is obtained. Thus the results shows analysis of PCB that is faulty or fault less and shows defected region of PCB.

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