

Genetic Algorithm Based Printed Circuit Board (PCB) Inspection System

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Abstract—This paper presents the first prototype of automating a low-cost printed circuit board (PCB) inspection on physical defects through the development of a technique for image detection using a Genetic Algorithm (GA). A GA is a powerful search technique which is applicable to various type of problems. The algorithm works on the principle of simulation of the evolution of individual structures via processes such as selection, mutation and crossover. This research aims to detect rotation angle and displacement of a board placed arbitrarily on a conveyor belt passing under the camera. Variant rotation and displacement values are represented as chromosomes to create a population which will evolve using GA operators and a specially tailored fitness function. Ideal parameter tuning of GA plays an important role in boosting the capability of this technique in order to perform effectively in the PCB inspection environment. Previous results regarding the use of GA on ARM based embedded PCB inspection system which focused on rotation and displacement of Integrated Circuits provides the motivation for this research. This research is run on Linux-based PC and real industrial samples PCB images are used in the implementation.

Index Terms—genetic algorithm (GA), image displacement, image rotation, printed circuit board (PCB).

I. INTRODUCTION

AUTOMATIC visual inspection is a crucial condition in today's production line of PCB. Many new techniques are studied to improve the quality of inspection and increase quantity of products in specified timeline.

Accurate placing the complete board on the conveyor belt under the camera is a hard task in order to produce good caption of board's image. Any misorientation of board's placement may lead to wrong analysis especially for reference-based method. For this reason, this research is proposed to estimate the rotation angle and displacement value of the board based on image captured using GA, while detecting any physical defects on the inspected board. This technique is based on referential matching between the stored reference image (golden board) and the test (captured) image.

Previously, [1] has used GA to find misorientation parameter's value of individual integrated circuits (IC) on board to determine the board has no defects and implemented the technique on system-on-chip platform. [2] also has used GA to estimate surface displacements and strains for autonomous inspection of structures. Both of works are successful and have given impressive results.

A. Genetic algorithms (GA)

Genetic algorithms are search algorithms based on the principles of natural selection / survival of the fittest to obtain

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reasonably good solutions to complex problems. Evolution of nature has inspired this search technique which consists of few elements (eg. population and individual) and processes (eg. mutation, crossover and selection). Individual with genetic information (or problem solution) are created to build a population. This population will go through every processes with a goal to discover the fittest individual based on the fitness function. It is assumed that the fittest individual will give the most optimum solution to the problem. Ideal setting of limiting conditions on GA such as mutation probability, crossover probability and population size plays an important role in boosting the capability of this technique in finding the best result.

II. IMPLEMENTATION

The proposed technique uses a perfect board to act as reference image and the test board. In this work, GA is used to derive the transformation between test and reference images based on the simple GA as presented in [3] in order to find out the board is good or faulty. It is essential to determine the type of encoding and the fitness function which will be used in the GA to optimize the parameters.

Many encoding schemes have been proposed, for example, integer coding and grey coding. There is no standard way to choose these schemes and the choice really depends on the nature expression of the problems. In this work, binary coding has been chosen since it is straight-forward and it is suitable for this problem. There are 19 bits as in Figure 1 are allocated which is nine bits for rotation for value from 0 to 360 degree, five bits for displacement of x-axis for value between -10 to 10 pixels and another five for displacement of y-axis for value between -10 to 10 pixels.



Fig. 1. The allocation of parameter in bit string for every individual

The fitness value is created to evaluate the string. The fitness function in this work is evaluated from total similarities values

in each pixels between test image and reference image divided by total pixels in reference image (It is assumed that both images are the same size).

A number of image processing operations are applied to both images to enhance the images and highlight the details. The reference board will be transformed using variant rotation and displacement values to create initial population for GA. Then, every transformed reference image is compared with the test image to evaluate the fitness value. There are many variations of GA operators and they are set in different values. Our purpose is to see the effectiveness of GA-guided parameter optimization. Therefore simple genetic algorithm (SGA) is used this research. However, we include elitism, which always include the best search point from the last iteration to the current iteration to prevent early convergence. The whole procedure in this research is described in the Figure 2. Few assumptions has been made in this simulation as listed below:

- 1) Both test and reference image are in same size.
- 2) Camera position and focus of the camera is constant across the samples.

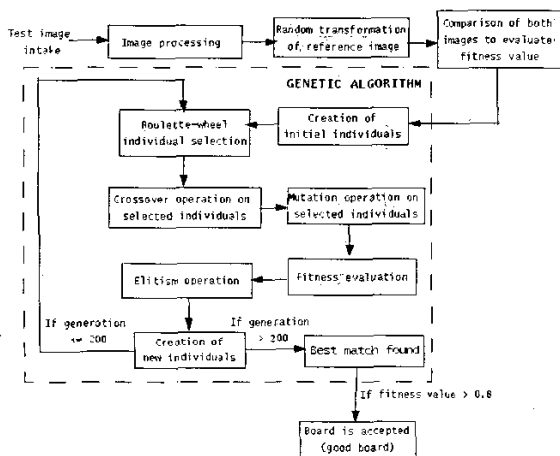


Fig. 2. Program flow-chart

III. ENVIRONMENT AND PARAMETERS

Performance study of GA-based printed circuit board inspection is conducted on a Linux-based PC and the images of printed circuit board is captured by black and white CCD camera. The basic image processing functions such as single global thresholding [4] and transformation is built using Vision Group's image library [5] and ImageMagick image library [6]. The thresholding is applied on every pixel by setting the value of object point, T equals to 100. A thresholded image defined as

$$g(x,y) = 0 \text{ if } f(x,y) \leq T$$

$$g(x,y) = 255 \text{ if } f(x,y) > T$$

where $f(x,y)$ is the gray level of point (x,y) in the image.

Fitness value is derived by comparing every pixel's value in both images (reference and test) and divided by total pixel in reference image. The reference image is displayed in Figure 3 and the test image is figured in Figure 4 and Figure 5.

Roulette-wheel selection which is a selection method of a new population with respect to the probability distribution based on fitness values, is combined with elitism in this work. The details of the GA parameters setting is shown in Table I.

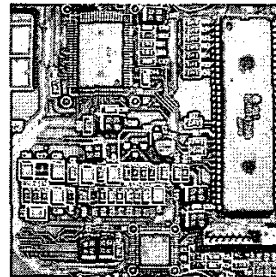


Fig. 3. Image of reference board

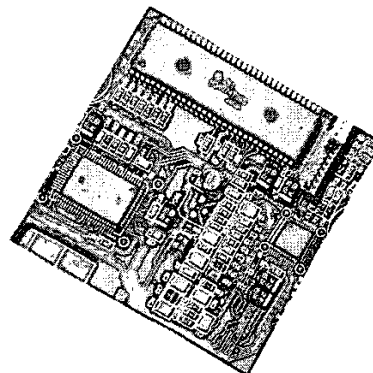


Fig. 4. Image of test board (good board)

TABLE I
VALUES OF PARAMETERS IN GA

Parameters	Setting Values
Generation	200
Population size	72
Crossover probability	0.5
Mutation probability	0.01

IV. RESULTS

We implemented this system model on a PC and it was run on two misorientated test images which are a good board (has no physical fault) and a faulty board (has one IC missing)

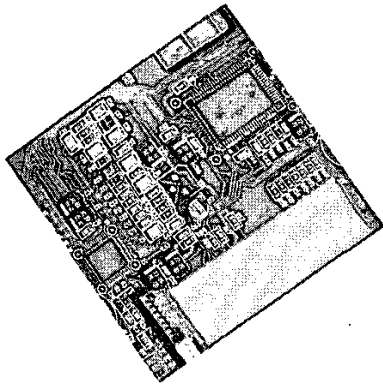


Fig. 5. Image of test board (faulty board)

for six times to evaluate the consistency of the results. This was also used for measuring the randomness of the random function that we used to initialize the first population and in GA operations of crossover and mutation.

From Figures 6 and 7, it is obvious that the results for the good board are quite consistent and the fitness values increases in all runs. The average best fitness value obtained from the runs are 0.86 and all the runs stopped increasing after generation 120. The best fitness value still did not reach 1.0 because there are few inaccuracy in the rotation value which is ± 2 degrees and displacement value in both axis has difference ± 4 pixels. It is observed that the quality of image has big impact on the accuracy of the results since this work is a reference-based method.

The consistency of the results in six runs continues during testing the faulty board as we can see the results plotted in Figure 8 and Figure 9. The maximum fitness value that can be reach is about 0.6 and the graph starts saturated at generation 150. The inaccuracy of transformation parameters about ± 2 degrees in rotation and ± 5 pixels in displacement at both axis gained at the end of run also influenced the best fitness value.

From best values gained in both test boards as shown in Figure 10, we can see the big difference in value which is about 0.26. In this implementation, these fitness values can be set as measurement points to determine the board is free from physical defects or not. However, this system not yet can recognize the type of defect if the board is detected as a faulty board. This may be investigated in future works for producing more accurate outputs from the system.

V. CONCLUSIONS

We have presented a novel technique using a GA for automatic detection of faults in printed circuit boards. The technique successfully detects the board with physical defects after 150 generations. Currently work is under way targeting advanced image enhancement and object recognition in order to further enhance the performance of this system.

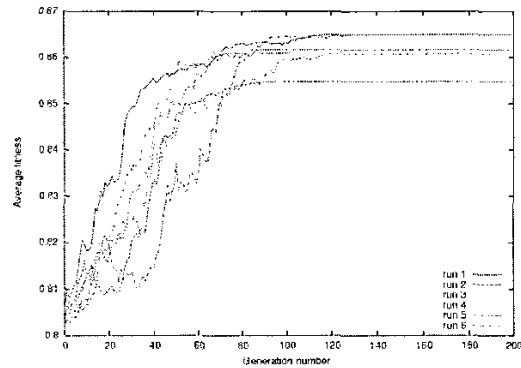


Fig. 6. Average fitness values vs generation number for good board for six runs

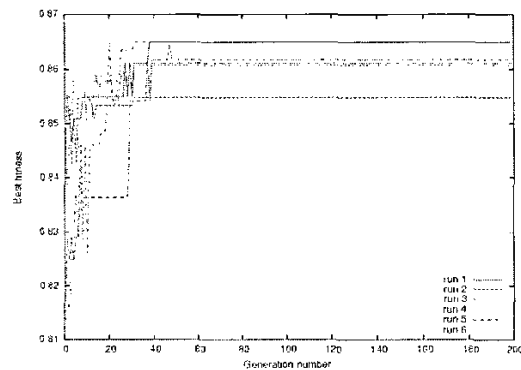


Fig. 7. Best fitness values vs generation number for good board for six runs

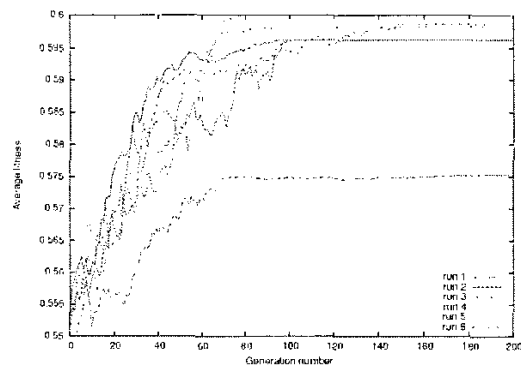


Fig. 8. Average fitness values vs generation number for faulty board for six runs

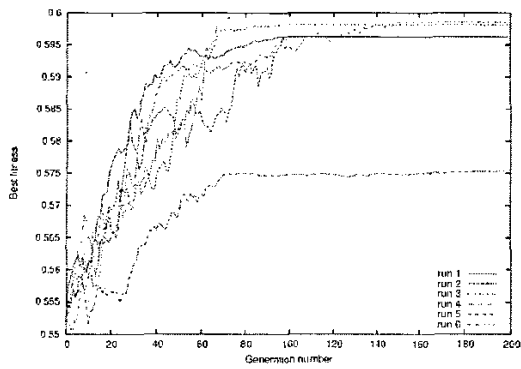


Fig. 9. Best fitness values vs generation number for faulty board for six runs

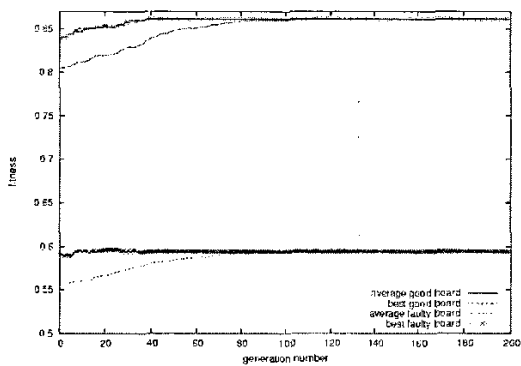


Fig. 10. Fitness values vs generation number for good test board and faulty test board

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